

## YPRESIAN ORGANIC-WALLED PHYTOPLANKTON IN THE BELGIAN BASIN AND ADJACENT AREAS

by

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(with 10 figures and 6 plates)

### ABSTRACT

In the Ypresian deposits of the Belgian basin about 315 species of fossil, organic-walled phytoplankton have up to now been found. Among these we have selected forty easily recognizable species which appear to be biostratigraphically useful. Their distribution in the Ypresian deposits of the Belgian basin, visualized in a projection on the compound profile of the Kallo-Woensdrecht reference section, has served as a base for the definition of eleven zones in this reference section. Assemblages of organic-walled phytoplankton from several outcrops and borings in the basin allow to make correlations with the zones in the Kallo-Woensdrecht reference section. This reference section can furthermore be correlated with sections in the surrounding basins of London, Hampshire, Dieppe, Paris, North Germany and Denmark, in which organic-walled phytoplankton assemblages had been described. From these correlations appears that the Ypresian sequence is nearly complete in the Danish basin, the northern Belgian basin and the Hampshire basin. The zonation of the Ypresian deposits in the Belgian basin, which we have introduced here, is somewhat more detailed than the zonations hitherto defined in the surrounding basins. It should be emphasized however that all these zonations remain tools to work with and that they will be adapted again in response to the growing insights in the changes of sedimentation and in the history of the life communities during the Ypresian times.

**Key words:** Ypresian, organic-walled phytoplankton, zonation, biostratigraphy, correlations, N.W. Europe.

### SAMENVATTING

In de afzettingen van het Ypresien in het Belgisch Bekken werden tot nog toe ongeveer 315 soorten van fossiel phytoplankton met organische wand teruggevonden. Onder die soorten hebben wij er een veertigtal uitgekozen die men gemakkelijk kan herkennen en die vanuit biostratigrafisch standpunt nuttig blijken. Hun verspreiding in de Ypresienafzettingen van het Belgisch bekken, geprojecteerd op het samengesteld profiel van de referentiesektie van Kallo-Woensdrecht, heeft als basis gediend voor de bepaling van elf zones in die sekte. Assemblages van phytoplankton met organische wand die voorheen werden bestudeerd in verscheidene ontsluitingen en boringen in het bekken, stelden ons in staat korrelaties te maken met de zones in de referentiesektie van Kallo-Woensdrecht. Daarenboven kan men die referentiesektie korreleren met sekties in de omliggende bekkens van Londen, Hampshire, Dieppe, Parijs, Noord-Duitsland en Denemarken, waarin assemblages van phytoplankton met organische wand waren beschreven. Uit die korrelaties komt naar voor dat de Ypresien sekwentie in het Deense bekken, het noorden van het Belgisch bekken en het Hampshire bekken praktisch volledig is. De zonering van de Ypresienafzettingen in het Belgisch bekken, die wij hier voorgesteld hebben, is iets meer gedetailleerd dan de zoneringen die tot nog toe gedefinieerd werden in de omliggende bekkens. Men mag echter niet uit het oog verliezen dat gelijk welke zonering slechts een werktuig is voor toepassing in de stratigrafie, en dat ze steeds weer aangepast dient te worden naarmate de inzichten in de veranderingen van de sedimentatie en in de geschiedenis van de leefgemeenschappen tijdens het Ypresian groeien.

**Sleutelwoorden:** Ypresien, phytoplankton met organische wand, zonering, biostratigrafie, korrelaties, N.W. Europa.

### RESUME

Dans les dépôts yprésiens du Bassin belge, environ 315 espèces de phytoplancton fossile, à paroi organique ont été retrouvées jusqu'à présent. Parmi elles, nous en avons sélectionné quarante qui sont facilement reconnaissables et qui paraissent utiles du point de vue biostratigraphique. Leur distribution dans les dépôts yprésiens du Bassin belge, visualisée dans une projection sur le profil composé de la section de référence de Kallo-Woensdrecht, a servi de base à la définition de onze zones dans cette section. Les assemblages de phytoplancton à paroi organique que l'on avait étudiés auparavant dans plusieurs affleurements et sondages dans le bassin, ont permis de faire des corrélations avec les zones dans la section de référence de Kallo-Woensdrecht. Par ailleurs, on peut corréler cette section de référence avec des sections dans les bassins de Londres, Hampshire, Dieppe, Paris, Allemagne du Nord et Danemark, dans lesquelles des assemblages de phytoplancton à paroi organique avaient été décrits. Ces corrélations mettent en évidence que la séquence yprésienne est quasi complète dans les bassins du Danemark, du nord de la Belgique et du Hampshire. Notre zonation des dépôts yprésiens du Bassin belge, que nous avons introduite ici, est un peu plus détaillée que les zonations qui avaient été définies jusqu'à présent dans les bassins avoisinants. Il faut toutefois insister sur le fait que toute zonation reste un outil dans le travail stratigraphique et qu'elle sera sans cesse adaptée en réponse à la compréhension grandissante des changements de la sédimentation et de l'histoire des communautés de vie durant l'Yprésien.

**Mots-clés:** Yprésien, phytoplancton à paroi organique, zonation, biostratigraphie, corrélations, Europe du N.W.

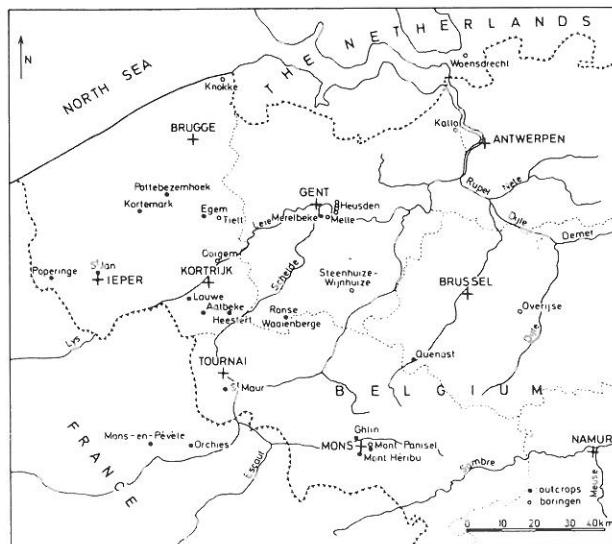


Fig. 1

Localisation of borings and outcrops.

Richly diversified assemblages of organic-walled phytoplankton, especially of dinoflagellate cysts, characterize the Ypresian deposits in the Belgian Basin. Their stratigraphical distribution in these deposits allows the definition of eleven zones. These are characterized by forty species with biostratigraphic significance in the basin. Our zonation is aligned with the ones proposed in the adjacent areas (Paris Basin, Hampshire-Dieppe Basin, London Basin, North Germany and Denmark).

## I. TOTAL DIVERSITY OF FOSSILIZED ORGANIC-WALLED PHYTOPLANKTON IN THE YPRESIAN OF THE BELGIAN BASIN

(localisation of borings and outcrops: fig. 1)

Chlorophyceae : 3 species  
Dinophyceae : 235 species  
Prasinophyceae : 30 species  
Acritarcha : 45 species

*Number of fossilized species which lived at the time of deposition:*

Chlorophyceae : 2  
Dinophyceae : 171  
Prasinophyceae : probably between 25 and 30  
Acritarcha : probably about 35

*Number of species reworked from the Jurassic:*

Chlorophyceae : —  
Dinophyceae : 21  
Prasinophyceae : ?  
Acritarcha : ?

*Number of species reworked from the Cretaceous:*

Chlorophyceae : —  
Dinophyceae : 36  
Prasinophyceae : ?  
Acritarcha : ?

*Number of species probably reworked from the Paleocene:*

Chlorophyceae : —  
Dinophyceae : 6  
Prasinophyceae : ?  
Acritarcha : ?

## II. DIVERSITY OF THE ASSEMBLAGES IN THE SAMPLES

The species diversity of fossilized Dinophyceae cysts produced at the time of sedimentation varies between about 25 and 65 in one sample; it attains an average of nearly 40 species. The number of fossilizable Chlorophyceae species fluctuates between 0 and 2. Prasinophyceae attain between 0 and 10 species in one sample, with an average of 5 species. Acritarcha diversity fluctuates between 0 and 15 species, with an average of 8 species per sample.

When an increase of the diversity is observed it occurs in general as well in Dinophyceae as in Prasinophyceae and Acritarcha. That possibly means that the stressing circumstances which favoured cyst formation among dinoflagellate species, also incited other phytoplankton groups to produce cysts (Acritarcha) or phycomae (Prasinophyceae).

Some trends in the changes of diversity can be commented: in the Mont Héribu Member, the Clay of Orchies and part of the Roubaix Clay, below the Glauconitic bed of Tielt, the diversity of Ypresian Dinophyceae + Prasinophyceae + Acritarcha is somewhat higher in the samples from Quenast, Mons-Mont Héribu, Orchies, Overijse, Mons-Ghlin and St Maur, averaging about 65 species, compared with the diversity in the samples from corresponding levels in the Kallo- and Tielt boring (DE CONINCK 1976a) and Knokke boring (DUPUIS et alii, in press) averaging about 40 species. It is probable that cyst production among many species was optimally favoured in the rather marginal parts of the basin (Overijse, Orchies...) in comparison with more offshore areas (Kallo, Tielt, Knokke). Such a positive effect on the diversity of cyst species is noted too in recent sediments of e.g. the Dutch Wadden Sea (personal observations) which contain cysts which probably were carried in the wadden area by the flooding waters coming from the open sea. These waters are in fact a mixture of North Sea water and estuarine Schelde, Maas and Rijn waters carried northwards along the Dutch coast towards the wadden areas.

Higher in the Ypresian deposits (above the Glauconitic bed of Tielt), when comparing the species diversity in samples from different localities in the basin, the differences observed seem fortuitous, not related to the place in the basin. When we compare in these higher ypresian deposits samples from successive levels at one locality (e.g. Kallo or Merelbeke or Woensdrecht) (DE CONINCK 1976a, 1977) we can observe here and there some marked differences in the number of species. This might suggest us that locally the

environmental circumstances fluctuated more all over the basin, becoming from place to place favourable for cyst production among more species during relatively short periods. But it could also correspond with a patchy distribution of these microfossils in the sediment, as we see that in one stratigraphic level at one locality, Quenast (DE CONINCK 1986), samples a few meters distant from each other clearly give different values for the diversity of species living at that same time of sedimentation (Quenast A3: 77 species; Quenast A4: 69 species).

### III. PALEOECOLOGICAL SIGNIFICANCE OF SOME SPECIES

— *Apectodinium homomorphum* (DEFLANDRE & COOKSON 1955) is considered as a species which lived in near-shore waters with lowered salinity (COSTA & DOWNIE 1976, p. 607). Its frequency is high to relatively high in the lowermost Ypresian beds in the Tielt- and Knokke borings (DE CONINCK 1976a; DUPUIS et alii 1985) but drops soon to sporadic occurrences (for instance at Knokke) immediately above these lowermost beds. Up to the higher part of the formation, but still below the Egem Sand the frequency remains near this zero level in the Kallo- and Tielt borings in areas situated at that time in rather offshore position. In equivalent deposits at Quenast, Mont Héribu, Orchies, Overijse, Ghlin and St Maur however the frequencies of *A. homomorphum* fluctuate between 1 and 6%; in these rather marginal areas of the Belgian Basin the influx of watermasses with lowered salinity carrying *A. homomorphum*, was apparently important. It may be the reason too why relatively more species of the phytoplankton produced cysts (see Trends in the changes of diversity) in these parts of the basin in comparison with the areas of Kallo, or Tielt situated more offshore. *A. homomorphum* comes back at Kallo, Tielt and Heestert in the upper part of the Aalbeke Clay or in the Kortemark Silt and remains well represented in the Egem Sand, for instance at Kallo, Merelbeke and Egem. Its frequency can attain high values such as 8 till 9 or even 20% (at Kallo – 259 m). Higher, in the Clay of Merelbeke, the species is well represented in the Kallo boring and especially in the Woensdrecht boring, but absent in the Melle-Heusden borings. It is not clear to me how from these data, the distribution of watermasses could be sketched in the period following the deposition of the Glauconitic bed of Tielt.

— *Impagidinium* spp. are considered to be indicators of oceanic watermasses (WALL et alii 1977, p. 168). In the lowermost part of the Ypresian deposits they have been found sporadically, only in the Knokke boring. At a biostratigraphically somewhat higher position in the Mont Héribu Member *Impagidinium* was strange enough only encountered at Overijse, Ghlin, St. Maur situated more near the border of the basin, and in the succeeding massive clay packet at Tielt (– 125.5 m), situated more offshore, each time very sporadically. In the upper part of the Roubaix Clay

(above the Glauconitic bed of Tielt), and in the succeeding Aalbeke Clay, Kortemark Silt, Egem Sand and Clay of Merelbeke, *Impagidinium* is regularly found in most of the borings and outcrops studied but frequencies remain low. In higher Ypresian deposits it becomes again very scarce. When we compare for the Kallo boring our observations with WILLEMS' interpretation (WILLEMS 1980, Ph.D. thesis) of the oceanic influence in the area of the basin, we see some correspondance only at – 283.5 m and – 280 m where frequencies of *Impagidinium* attain 2% and at which levels WILLEMS indicated a marked influence from open sea. At other levels in the Ieper Formation where according to WILLEMS (*ibid.*) an open sea influence clearly comes forward, no *Impagidinium* were however found (– 329.5 m, – 315 m and – 303.9 m). To be really paleoecologically significant, the frequencies of *Impagidinium* spp. should probably attain higher values.

— *Pediastrum* sp. is a freshwater Chlorophyceae species. It is nearly absent from the base of the Ypresian deposits to the top of the Egem Sands. It suddenly appears in the Clay of Merelbeke (Kallo boring, Melle-Heusden borings, Torhout Pottebezemhoek) and is regularly observed further in the Upper Ypresian deposits (Kallo, Woensdrecht, Melle-Heusden, Egem Ampe). Apparently the paleogeographic conditions changed after the sedimentation of the Egem Sands and were accompanied by freshwater influx in many parts of the basin. Perhaps some "wadden islands" developed temporarily in the very shallow basin and produced a freshwater vegetation among which *Pediastrum*, which was transported into the sea (?).

### IV. TRENDS IN THE DISTRIBUTION OF REWORKED SPECIES

We are going to consider here the reworked dinoflagellate species only, not the eventually reworked Prasinophyceae and Acritarcha. Species reworked from Paleocene deposits have only been encountered in the Mont Héribu Member at Orchies, St Maur, Mont Héribu and Quenast.

Among the Mesozoic species, those reworked from the Jurassic are rather restricted to the Mont Héribu Member, the Orchies Clay and the lower part of the Roubaix Clay below the Glauconitic bed of Tielt, while those reworked from the Cretaceous are present from the Mont Héribu Member up to the base of the Egem Sand. They are found all over the basin.

When counted together, the procentual frequencies of the reworked Jurassic and Cretaceous species average about 5% in the Mont Héribu Member and the Orchies Clay, below our *Eatonicysta ursulae* zone (see the proposed zonation under V), but can attain 10% (Kallo – 337 m, Orchies; Ghlin, St. Maur) or exceptionally 18% (Mont Héribu). From the base of the Roubaix clay (*Eatonicysta ursulae* zone) up to the top of the Kortemark Silt, the frequencies of both species groups together average about 2.5%. In the higher deposits reworked species were almost never

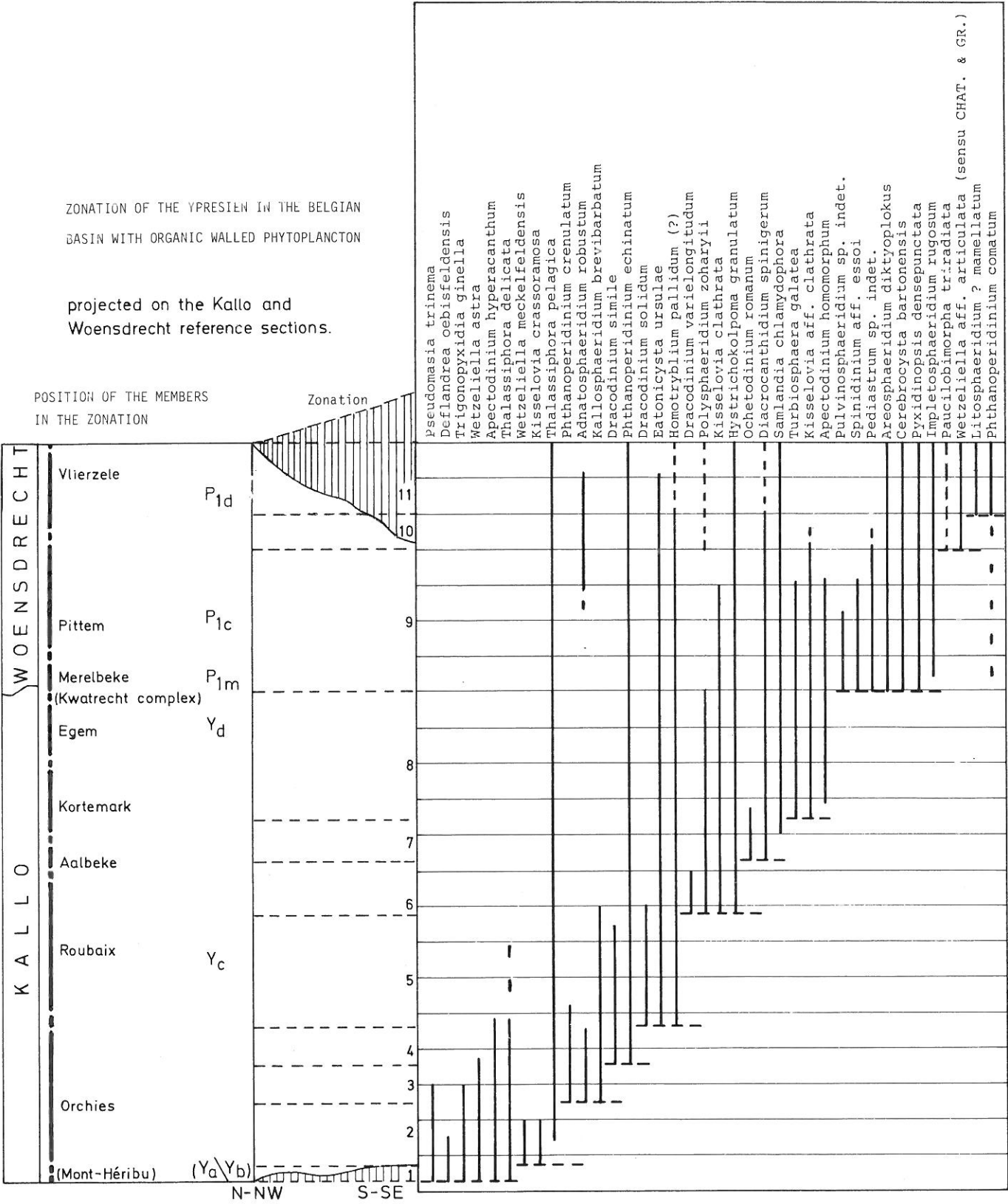


Fig. 2  
Stratigraphic distribution of biostratigraphically useful species and proposed zonation.



recorded. From this trend we can conclude that erosion of Mesozoic deposits around the Belgian Basin was more pronounced in the earliest times of the Ypresian than later in the Lower Ypresian, and that it almost stopped around the time when the sedimentation of the Egem Sand started.

## V. SPECIES WITH RESTRICTED STRATIGRAPHIC DISTRIBUTION IN THE BELGIAN BASIN

**Selection of biostratigraphically useful species** (fig. 2).

In DE CONINCK (1981, table 1) some forty species are retained as useful tools for biostratigraphic correlations in the Ypresian deposits only, and at the scale of the only Belgian Basin. Some of these species have been found in Paleocene deposits and are still encountered in the lower part of the Ypresian sequence (e.g. *Deflandrea phosphoritica*, *Alisocysta margarita*, *Apectodinium hyperacanthum* and *Thalassiphora delicata*); or they left temporarily the Belgian Basin and came back later in the Ypresian (e.g. *Thalassiphora pelagica*, *Phthanoperidinium crenulatum*, *Homotryblum* sp., *Polysphaeridium zoharyi*, *Apectodinium homomorphum*...). Other species are encountered in relatively short parts of the sequence, in for instance the lower Ypresian deposits, disappear temporarily and come back near the top of the Ypresian (e.g. *Adnatosphaeridium robustum*) or even later in the Lutetian (e.g. *Phthanoperidinium crenulatum*). It is quite certain that the presence or absence of these species during parts of the Ypresian time in the Belgian Basin must have been linked to the shifting distribution of particular watermasses in which these species produced cysts or to which they were restricted. Not only the Belgian Basin must have been affected by such a changing distribution of watermasses but also the adjacent areas. Hence it is normal that the more the synchrone sequences are distant from each other or separated by paleogeographic barriers, the more the stratigraphic distribution of several species will differ from one area to another. Only the most tolerant thus the more pronounced cosmopolitan species will be suitable for biostratigraphic correlations on a large scale. More data must however be assembled before selecting species combining a restricted stratigraphical distribution and a marked cosmopolitan character

### Proposal of a zonation of the Ypresian deposits in the Belgian Basin with organic-walled phytoplankton

A few zonations with organic-walled phytoplankton covering the Ypresian exist already: they take into account the dinoflagellates (BUJAK et alii 1980) or only one group of them, the *Wetzeliiellaceae* (COSTA & DOWNIE 1976, COSTA & MULLER 1978, CHATEAUNEUF & GRUAS-CAVAGNETTO 1978). In the zonation proposed here we have used 34 dinoflagellate cyst species, 3 species of acritarchs and one Chorophyceae species. In fig. 2 the stratigraphic

distribution of these species in the Ypresian deposits of the Belgian Basin is projected on the combined sections of the Kallo boring for the lower members up to the Merelbeke Clay and of the Woensdrecht boring for the Merelbeke Clay up to the Vlierzele Sand. From one area to another in the Belgian Basin the boundaries between the zones may vary slightly with respect to the boundaries between the members (see VI, and fig. 9).

#### 1. *Pseudomasia trinema* Zone

This zone represents the lowermost part of the Ypresian deposits in the Belgian Basin. The acritarch *P. trinema* DE CONINCK 1969 is chosen because it is easily recognisable and in the Belgian Basin it has until now been encountered in the lower part of the Ypresian sequence only and never in older deposits. In the zone one occasionally finds *Wetzeliiella astra* COSTA, DENISON & DOWNIE 1977. The upper limit of the zone is defined by the appearance of *Wetzeliiella meckelfeldensis* GOCHT 1969 and/or *Kisselovia crassoramosa* (WILLIAMS & DOWNIE 1966). In the *P. trinema* Zone some other species which in other basins have been found in older deposits too are worth mentioning: *Deflandrea oebisfeldensis* ALBERTI 1959, *Trigonopyxidia ginella* (COOKSON & EISENACK 1960), *Thalassiphora delicata* WILLIAMS & DOWNIE 1966 and *Apectodinium hyperacanthum* (COOKSON & EISENACK 1965). From observations in lower Ypresian deposits from the Rockall Plateau (BROWN & DOWNIE 1984) it seems that *W. astra* appears somewhat prior to *P. trinema*.

#### 2. *Wetzeliiella meckelfeldensis* — *Kisselovia crassoramosa* Zone

At the base of the zone both *W. meckelfeldensis* and *K. crassoramosa* appear approximately together. *K. crassoramosa* seems restricted to this zone. *Pseudomasia trinema* can still be found as well as the other species mentioned in the first zone. *Thalassiphora pelagica* (EISENACK 1954) which had left the basin near the end of the Thanetian comes back in this zone. The top of the zone is defined by the come back of *Phthanoperidinium crenulatum* (DE CONINCK 1976) which was already present in part of the Thanetian deposits (HEILMANN-CLAUSEN 1985, p. 25) in Denmark and SE England.

#### 3. *Phthanoperidinium crenulatum* Zone

*P. crenulatum* is found at the base of the zone in company of *Adnatosphaeridium robustum* (MORGENROTH 1966) and *Kallosphaeridium breviarbatum* DE CONINCK 1969. In the zone we note the last occurrence of *P. trinema*, *Trigonopyxidia ginella* and *W. astra*. *Thalassiphora pelagica* remains present and will be found in the younger zones too. The top of the *P. crenulatum* Zone is defined by the first appearance of *Dracodinium simile* (EISENACK 1954).

#### 4. *Dracodinium simile* Zone

Together with the appearance of *D. simile* at the base of this zone we note the first *Phthanoperidinium echinatum* EATON 1976. *P. crenulatum* and *K. brevibarbatum* are still present. *A. robustum* leaves the assemblages near the top of the zone while *Thalassiphora delicata*, without disappearing, becomes very scarce. The top of the *Dracodinium simile* Zone is defined by the first occurrence of *Eatonicysta ursulae* (MORGENROTH 1966).

#### 5. *Eatonicysta ursulae* Zone

Together with the appearance of *E. ursulae* at the base of the zone we note the come back of *Homotryblum* (probably *H. pallidum*) which had already been observed in Upper Thanetian deposits (DUPUIS & GRUAS-CAVAGNETTO 1985 and DUPUIS *et al.*, in press), and the appearance of *Dracodinium solidum* GOCHT 1955. *P. crenulatum* disappears in the base of the zone and will temporarily come back in the Lutetian. *D. simile* and *D. solidum* disappear near the top of the zone. *K. brevibarbatum* and *P. echinatum* remain present. The top of the *E. ursulae* Zone is defined by the appearance of *Dracodinium varielongitudum* (WILLIAMS & DOWNIE 1966).

#### 6. *Dracodinium varielongitudum* Zone

Together with the appearance of *D. varielongitudum* at the base of the zone we note the come back of *Polysphaeridium zoharyi* (ROSSIGNOL 1962) which was already encountered in Upper Thanetian deposits in the Knokke boring (DUPUIS *et al.*, in press). *Hystrichokolpoma granulatum* EATON 1976 and *Kisselovia clathrata* (EISENACK 1938) [which corresponds quite certainly to *K. coleothrypta* (WILLIAMS & DOWNIE 1966)] make their first appearance. *K. brevibarbatum* disappears in the lowermost part of the zone, while *D. varielongitudum* disappears near its top. *P. echinatum*, *H. pallidum* (?) and *Eatonicysta ursulae* remain present. The top of the *D. varielongitudum* Zone is defined by the appearance of *Ochetodinium romanum* DAMASSA 1979.

#### 7. *Ochetodinium romanum* Zone

*O. romanum* appears at the base of the zone together with *Diacrocantidium spinigerum* DE CONINCK 1969. *P. echinatum*, *H. pallidum* (?), *E. ursulae*, *H. granulatum* and *P. zoharyi* remain present while *K. clathrata* becomes more frequent. *Samlandia chlamydophora* EISENACK 1954 appears within this zone. *O. romanum* disappears at the top of the zone which is defined by the appearance of *Kisselovia aff. clathrata* (EISENACK 1938) (*sensu* DE CONINCK 1976a).

#### 8. *Kisselovia aff. clathrata* Zone

Together with the appearance of *K. aff. clathrata* (*sensu* DE CONINCK 1976a) at the base of the zone we note the appearance of *Turbiosphaera galatea*

EATON 1976. *D. spinigerum*, *P. zoharyi*, *H. granulatum*, *K. clathrata*, *H. pallidum* (?), *E. ursulae*, *P. echinatum* and *Samlandia chlamydophora* remain present. Within the zone *Apectodinium homomorphum*, which is sporadically present in the lower zones, becomes more frequent. The top of the *K. aff. clathrata* Zone is defined by the appearance of *Areosphaeridium diktyoplokus* (KLUMPP 1953).

#### 9. *Areosphaeridium diktyoplokus* Zone

Together with the appearance of *A. diktyoplokus* at the base of the zone we encounter for the first time *Spinidinium aff. essoii* COOKSON & EISENACK 1967, *Pediastrum* sp., *Pulvinosphaeridium* sp., *Cerebrocysta bartonensis* BUJAK 1980 (sporadically) and *Pyxididopsis densepunctata* DE CONINCK 1985 (= *Tectatodinium* sp. in DE CONINCK 1977 or *Pyxididopsis* sp. 1 in DE CONINCK 1981). *P. zoharyi* leaves the basin temporarily at the base of the zone and will appear again in the following zone. *Pulvinosphaeridium* sp. and *S. aff. essoii* disappear well below the top of the zone and *K. clathrata*, *T. galatea* and *A. homomorphum* near the top. *P. echinatum*, *E. ursulae*, *H. pallidum* (?), *H. granulatum*, *D. spinigerum*, *K. aff. clathrata*, *S. chlamydophora* and *A. biformoides* remain present and *Impletosphaeridium rugosum* MORGENROTH 1966 appears in the lower part of the zone. The top of the *A. diktyoplokus* Zone is defined by the appearance of *Paucilobimorpha triradiata* DE CONINCK 1986.

#### 10. *Paucilobimorpha triradiata* Zone

*P. triradiata* (= *Incertae Sedis* B and C in DE CONINCK 1976a, b, 1977, 1985) appears at the base of the zone. Its frequency remains however very low. *P. zoharyi* which had temporarily left the basin during deposition of the former zone comes back, but rather sporadically. *E. ursulae*, *H. pallidum* (?), *H. granulatum*, *D. spinigerum*, *S. chlamydophora*, *A. biformoides*, *A. diktyoplokus*, *C. bartonensis*, *P. densepunctata* and *I. rugosum* remain present. *K. aff. clathrata* and *Pediastrum* rarify near the base, then disappear. Together with *P. triradiata* appears *W. aff. articulata* EISENACK 1938 *sensu* CHATEAUNEUF & GRUAS-CAVAGNETTO 1978 (= *W. articulata — ovalis* in DE CONINCK 1977). The top of the *P. triradiata* Zone is defined by the appearance of *Litosphaeridium? mamellatum* DE CONINCK 1977.

#### 11. *Litosphaeridium? mamellatum* Zone

*L. ? mamellatum* appears at the base of the zone. *Phthanoperidinium comatum* (MORGENROTH 1966) which was encountered very sporadically in the *A. diktyoplokus* zone and the *P. triradiata* zone becomes now rather frequent. *H. granulatum*, *P. zoharyi*, *S. chlamydophora*, *A. biformoides*, *A. diktyoplokus*, *C. bartonensis*, *P. densepunctata*, *I. rugosum*, *P. triradiata* and *W. aff. articulata* (*sensu* CHATEAUNEUF & GRUAS-CAVAGNETTO

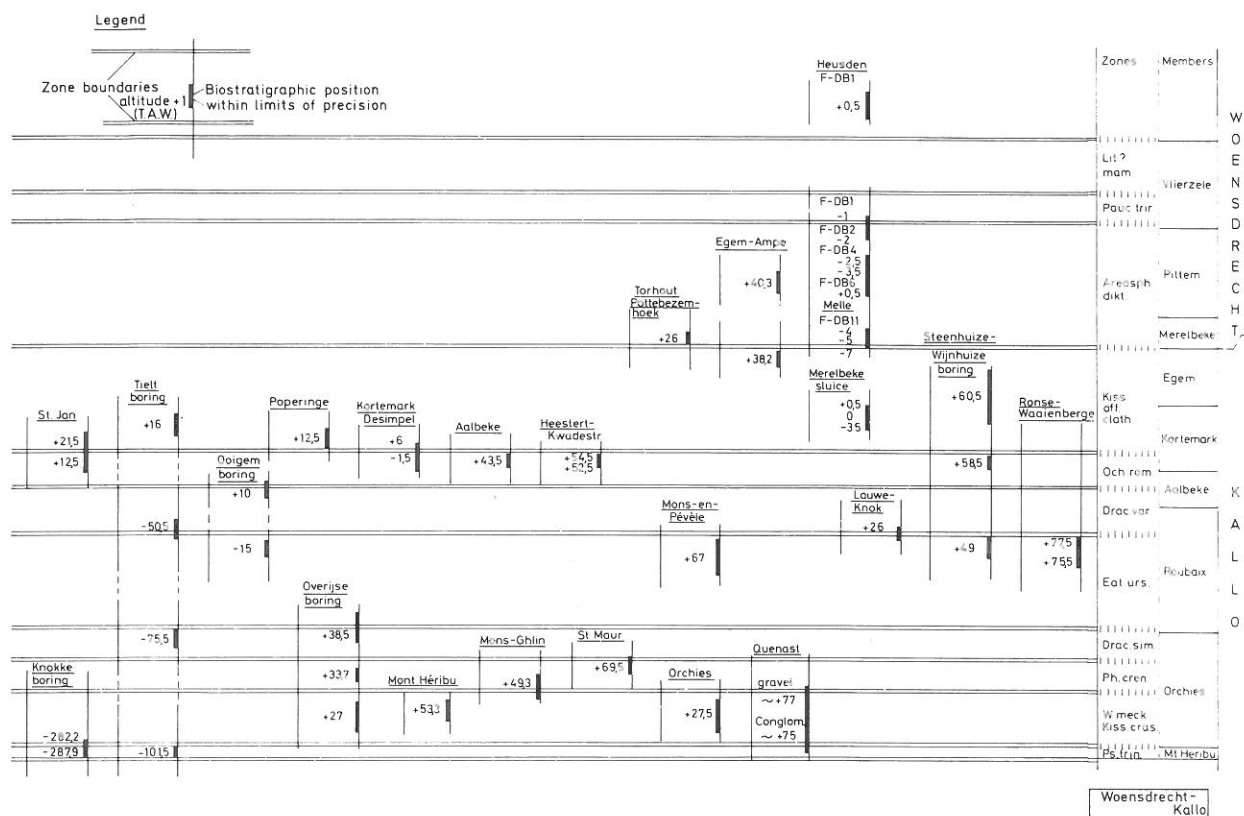


Fig. 3

Biostratigraphic correlations within the Belgian Basin with the Kallo-Woensdrecht reference section.

1978) remain present. In the zone disappears *E. ursulae* while *H. pallidum* (?) and *D. spinigerum* rarify or disappear temporarily. The top of the zone is defined by the appearance of *Dracodinium pachydermum* (CARO, 1973). The transition Ypresian/Lutetian is probably situated near the top of the zone.

## VI. BIOSTRATIGRAPHIC POSITION OF THE YPRESIAN DEPOSITS IN THE BELGIAN BASIN

The assemblages of organic-walled microfossils studied in the Ypresian deposits in several outcrops and borings in the Belgian Basin (fig. 1), make biostratigraphic correlations possible with the zones in the combined reference section of the Kallo and Woensdrecht borings (fig. 3).

### A. The base of the Ypresian deposits at Kallo, Tielt, Knokke, Overijse, Quenast, Mont Héribu and Orchies

In the borings of Kallo, Tielt and Knokke the base of the Ypresian deposits corresponds with the *Pseudomasia trinema* Zone which is grosso modo the equivalent of the *Wetzeliella astra* Zone defined by COSTA, DENISON & DOWNIE (1978). In these localities of the northwestern part of the Belgian Basin the transgression was almost synchrone. At Overijse, Mont Héribu and Orchies,

localities situated near the southeastern border of the basin, the transgression started at the time of deposition of the *Wetzeliella meckelfeldensis* — *Kisselovia crassoramosa* Zone, thus a little later than at Kallo, Tielt or Knokke. At Quenast, situated somewhat more centrally, the microdioritic intrusion on which the Ypresian deposits were laid down, formed probably an island during the times when sediments of the *Pseudomasia trinema* Zone and the *Wetzeliella meckelfeldensis* — *Kisselovia crassoramosa* Zone were deposited in the surrounding sea. The volcanic intrusion must have been submerged and reduced to some rocks in the Ypresian sea from the time when deposits of the *Phthanoperidinium crenulatum* Zone were found.

### B. Some higher levels in the Ypresian sequence

1. *THE ROUBAIX CLAY*. Apart from the Roubaix Clay in the Kallo, Ooigem and Tielt borings, this unit was studied near its type area at Lauwe Knok in an abandoned claypit of the "Céramiques et Briqueteries du Littoral". A sample, taken by MOORKENS in 1968 at about 4 m below a silty bed with numerous *Turritella* specimens, contains an assemblage of organic-walled microfossils which has an intermediary composition between the ones found in the Kallo boring at -307 m and at -303.9 m, respectively below and above a glauconite level at -305 m (Glauconiferous Bed of Tielt) (cf. DE CONINCK



1976b). The same sample from Lauwe Knok was studied by STEURBAUT (STEURBAUT & NOLF, 1986). The calcareous nannofossil assemblage which he recovered corresponds more to the one at Kallo – 301,5 m than that at – 304,6 m. It is correlated with in the base of the zone IV proposed by STEURBAUT (*ibid.*). The transition between zone IIIb and zone IV is situated at Kallo between – 304,6 m and – 301,5 m while the transition between the *E. ursulae* Zone and the *D. varielongitudum* Zone is situated at Kallo between – 307 m and 303,9 m. From the study of both the organic-walled microfossils and the calcareous nannofossils we are inclined to correlate the Lauwe sample with a part of the sequence at Kallo between – 304,6 m and – 303,9 m, in the middle of the Roubaix Clay encountered in that boring.

*Remark:* As we shall see later, when correlating the deposits in the Belgian Basin with those in the surrounding basins, there exists probably a gap in sedimentation in the Kallo area at the level of the Glauconiferous Bed of Tielt. Elsewhere in the Belgian Basin the corresponding sedimentary gap may be more or less pronounced. It is probable that in the Lauwe area the level studied corresponds to a part of the sedimentary gap at Kallo.

2. THE SANDS OF MONS-EN-PEVELE have been studied at the type-locality, also in the southern part of East Flanders, namely at Ronse "Waaenberge" and at Steenhuize-Wijnhuize.

#### a) Mons-en-Pévèle

A sample was taken by GEETS (doctorate thesis 1969) near the road from Mons-en-Pévèle to Bersée, at a point situated about 1 km to the east of the center of Mons-en-Pévèle. It comes quite certainly from the lower part of the unit which rests there on the Orchies Clay. The assemblage of organic-walled microfossils, studied by VANHOVE (*in prep.*), suggests a biostratigraphic correlation with the upper part of the *E. ursulae* Zone at Kallo. STEURBAUT, after studying the calcareous microfossils in the same sample of the Mons-en-Pévèle Sands (STEURBAUT & NOLF, 1986), made a correlation with his zone IIIa in the Kallo boring (= uppermost part of the NP11 Zone) which corresponds to the upper part of the *E. ursulae* Zone. Both microfossil groups suggest thus the same correlation.

#### b) Ronse "Waaenberge"

Two samples taken in the talud of an old railway cutting come from clayey sands with nummulite accumulations respectively at about 7 m and 5 m below the local Aalbeke Clay at the top of the talud. The assemblages of organic-walled microfossils studied by VANHOVE (*in prep.*) allow to make a biostratigraphic correlation with the upper part of the *E. ursulae* Zone in the Kallo boring. The same sands, studied again at about 7 m below the Aalbeke Clay, contain calcareous nannofossils studied by STEURBAUT (STEURBAUT & NOLF, 1986) who proposes a correlation with his zone IIIa (= uppermost part of the NP11 Zone) in

the Kallo boring. Here again both microfossil groups suggest the same correlation.

#### c) Steenhuize-Wijnhuize

In a boring of the Belgian Geological Survey at Steenhuize-Wijnhuize (about halfway Ronse and Aalst) the Sands of Mons-en-Pévèle were studied at about 4,5 m below the local Aalbeke Clay (VANHOVE, *in prep.*). The organic-walled microfossils suggest a correlation with the *E. ursulae* zone at Kallo. STEURBAUT (*ibid.*, 1986) has studied the calcareous nannofossils near the same level and can correlate the assemblage with his zone IIIb (= lowermost part of NP12 Zone). From these data we can conclude that this level in the Steenhuize-Wijnhuize boring can be correlated with the uppermost part of the *E. ursulae* Zone at Kallo.

*Conclusion:* The Sands of Mons-en-Pévèle in the southern part of East Flanders correspond for a large part to (the upper part of) the *E. ursulae* Zone at Kallo, thus to the middle part of the local Roubaix Clay. At the type locality Mons-en-Pévèle the sample in the lower part of the unit corresponds to the same middle part of the Roubaix Clay at Kallo. It is possible that the higher parts of the Sands of Mons-en-Pévèle outcropping in the hill immediately to the northwest of the village of Mons-en-Pévèle correspond to the higher part of the Roubaix Clay at Kallo as well as in its type area.

3. AALBEKE CLAY. Apart from the Aalbeke Clay in the Kallo boring, this unit was studied (DE CONINCK, 1976c) in a claypit situated at about 1 km to the southeast of the center of Aalbeke, near the road from Aalbeke to Rollegem. The sample studied was collected by GEETS (doctorate thesis, 1969) at 8,5 m below the surface (at 43,5 m T.A.W.). Further research on organic-walled microfossil assemblages from the Aalbeke Clay was done by VLERICK (licentiate thesis, 1982) in a claypit at Heestert-Kwadestraat and by VANHOVE (*in prep.*) in the boring at Steenhuize-Wijnhuize. In all these studies of the Aalbeke Clay in its type-area and in the southern part of East Flanders, only the upper part of the unit was investigated. The assemblages of dinoflagellates encountered in that upper part of the Aalbeke Clay in the southern part of the Belgian Basin are comparable to these in the upper half of the *O. romanum* Zone at Kallo, but in that boring the upper half of this zone is situated in the lower part of the local Kortemark Silt just above the local Aalbeke Clay. The fact that the same upper half of the *O. romanum* Zone is found in the lower part of the Kortemark Silt in the Kallo boring and in the upper part of the Aalbeke Clay in its type-area illustrates the slight diachronism of the boundary between both lithostratigraphic units when different areas of the basin are compared with each other.

4. THE EGEM SANDS — MERELBEKE CLAY TRANSITION AT KALLO OR THE EGEM SANDS — PITTEM CLAY TRANSITION AT EGEM. In both localities a rather superficial



investigation of the changes of assemblages from the lower unit to the overlying one suggests that there may exist a sedimentary gap at this transition. The number of samples covering that transition is in both cases however too small to be able to evaluate such an eventual gap, if any. Further studies to elucidate the eventual existence of a sedimentary gap at the top of the Egem Sands and its importance at Kallo on the one hand, at Egem on the other hand, or eventually elsewhere in the basin, are in progress.

**5. THE TRANSITION OF THE VLIERZELE SANDS TO THE OVERLYING AALTER SANDS AT HEUSDEN.** The Vlierzele Sands — Aalter Sands transition was studied at Heusden (DE CONINCK, 1976c) in a boring about 6 km to the east of the center of Gent, halfway between Destelbergen and Laarne. We were able to demonstrate, after studying the organic-walled microfossil assemblages, that the local top of the Vlierzele Sands corresponds approximately to – 415 m in the Woensdrecht boring studied at the mean time (DE CONINCK 1977). The overlying local Aalter Sands correspond approximately to – 375 m in the Woensdrecht boring. From this observation appears that an important sedimentary gap exists in the region of Heusden between the local Vlierzele Sands and the overlying Aalter Sands. That gap corresponds grosso-modo to the upper part of the *P. triradiata* Zone, to the *L. ? mamellatum* Zone and to some

higher deposits beyond the Ypresian-Lutetian transition up to – 375 m in the Woensdrecht boring. We can conclude from this information that the upper limit of the Vlierzele Sands (i.e. the Aalterbrugge Complex) becomes younger when going from the central area of the Belgian Basin towards its northern part.

## VII. BIOSTRATIGRAPHIC POSITION OF THE YPRESIAN DEPOSITS IN THE ADJACENT BASINS

### A. London Basin

Several correlations between the Ypresian deposits in the Kallo-Woensdrecht section of the northern Belgian Basin and sections through the Ypresian deposits in the London Basin are proposed in fig. 4 (lithostratigraphy according to KING 1981 & 1984 and HAWKINS 1955). They are based on the first appearance or on the top of the range of some dinoflagellate species which are encountered in these deposits.

In the western part of the London Basin information is available on the succession of dinoflagellate species in a few borings of the Enborne Valley: The Baughurst boring n° 2 was described in HAWKINS (1955, pp. 409-430, text-fig. 6) and in KING (1981, pp. 67-69, text-fig. 21); its dinoflagellates were studied by ISLAM (1983, pp. 74-75, text-fig. 2). The Enborne boring n° 11 was figured by HAWKINS

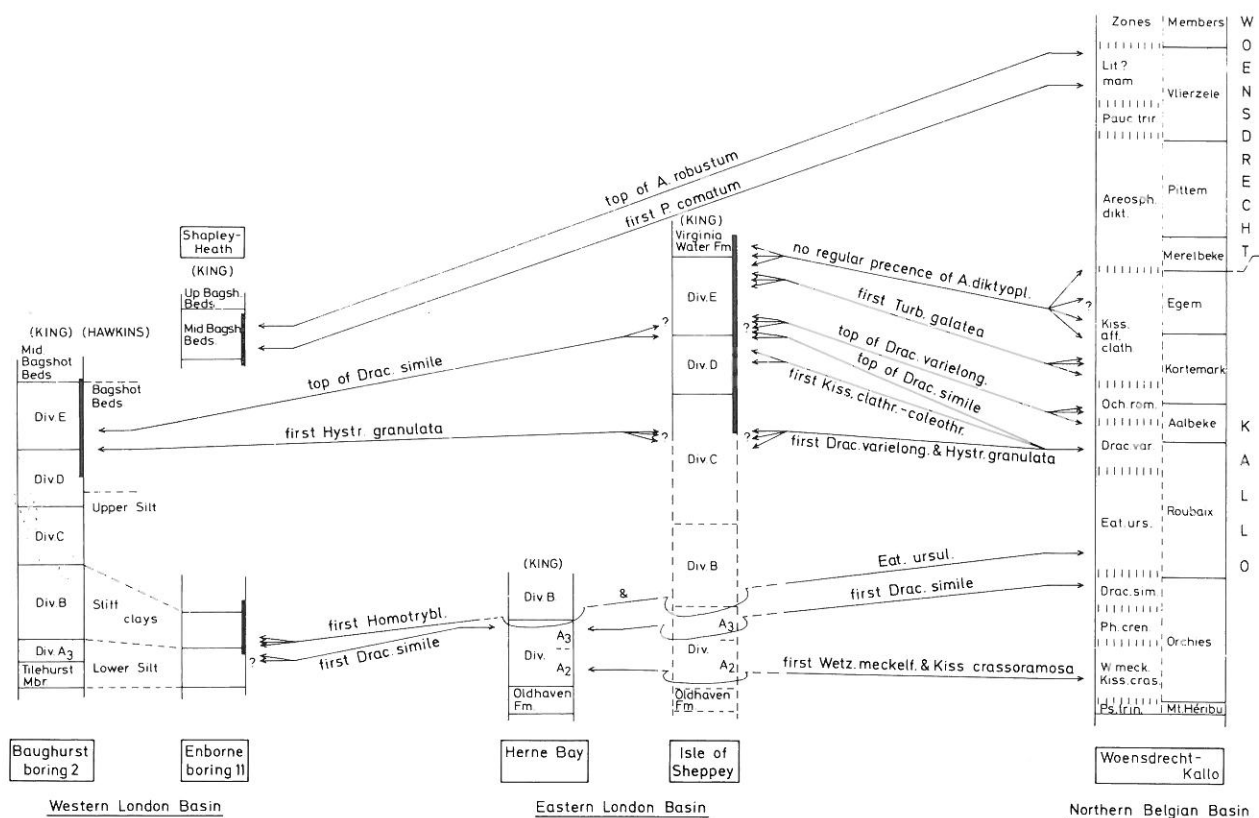


Fig. 4  
Biostratigraphic correlations  
between London Basin sections  
and the Kallo-Woensdrecht reference section.

(1955, text-fig. 4) and its dinoflagellates were studied by G.L. WILLIAMS and DOWNIE (in DAVEY *et al.*, 1966, pp. 20-27, table 1, text-fig. 7). From an outcrop at Shapley-Heath, a little more to the east, some information (ISLAM 1983, text-fig. 3, p. 75), can be used.

In the eastern part of the London Basin the sections at Isle of Sheppey and at Herne Bay have been retained. At Isle of Sheppey the deposits are described in KING (1981, pp. 52-54, text-fig. 15) and in KING, 1984. ISLAM (1984) studied the dinoflagellate assemblages. The Herne Bay section is described in KING (1981, pp. 54-56, text-fig. 22) and information about the appearance of some Wetzeliellaceae spp. was found in COSTA & DOWNIE (1976, p. 600).

## COMMENTS

### • Basal Ypresian deposits

The *P. trinema* Zone in the lowermost part of the Ypresian sequence at Kallo in the northern Belgian Basin corresponds with the lower part of the London Clay Div. A<sub>2</sub> (Walton Member) in the London Basin. It is grosso modo the equivalent of the *W. astra* Zone defined by COSTA, DENISON & DOWNIE (1978). *P. trinema* has been recorded as Gen. et sp. indet. III by BROWN & DOWNIE (1984, text-fig. 2) shortly higher than the earliest appearance of *W. astra* in the Rockall area (N. Atlantic).

In the London Basin the London Clay Div. A<sub>1</sub> (Harwich Member and Swanscombe Member) are older than the *P. trinema* Zone at Kallo, and older than the *W. astra* Zone. This Div. A<sub>1</sub> and equivalent deposits in the North Sea Basin are characterized by the presence of volcanic ash deposits and marked by peaks in the frequency (acme) of *Deflandrea oebisfeldensis* (KNOX & HARLAND, 1979, pp. 465-466). They can however not be much older than the *P. trinema* Zone. Indeed, relatively high frequencies of *D. oebisfeldensis* are noted in the basal eighty cm of the Ypresian deposits in the Kallo boring just below the first record of *P. trinema*, and also in the basal four metres of the Ypresian sequence in the Knokke boring (Belgian coast) where *P. trinema* has been found only once at four metres above the base of the Ypresian sequence (DUPUIS *et al.*, in press). These data suggest that the Zone with the *D. oebisfeldensis* acme situated in the London Clay Div. A<sub>1</sub>, may eventually correspond with the lowermost Ypresian deposits in the north-(western) Belgian Basin.

Further research is however needed before this can be confirmed.

### • The *E. ursulae* Zone — *D. varielongitudum* Zone transition

In the northern Belgian Basin (Kallo boring) it seems that the sedimentation nearly stopped between the *E. ursulae* Zone and the *D. varielongitudum* Zone. Indeed, the following difference is seen between Kallo and Isle of Sheppey: At the base of the *D. varielongitudum* Zone at Kallo appear *D. varielongitudum*, *K. clathrata*-

*coleothrypta* and *H. granulata* while *D. simile* disappears. In the Isle of Sheppey section one notes that *D. varielongitudum* and *H. granulata* appear probably near the middle of Div. C while *K. clathrata-coleothrypta* appears near the middle of Div. D and *D. simile* disappears around the base of Div. E. From this picture one can conclude that the upper part of Div. C and probably the whole Div. D were deposited in the eastern London Basin while at Kallo in the northern Belgian Basin the sedimentation was very slow if not interrupted. During this lapse of time the glauconitic level at Kallo – 305 m was formed. This glauconite horizon has been correlated with the one recorded at Tielt – 101,5 m and called Glauconiferous Bed of Tielt (DE CONINCK, 1976a, p. 27).

When we correlate this part of the sequence at Isle of Sheppey with the one in the Baughurst boring in the western London Basin we see that at Baughurst the corresponding sequence is much thinner and situated in the lower part of Div. E (in the middle of the Bagshot Beds *sensu* HAWKINS, 1955). If these lithostratigraphical and biostratigraphical interpretations are correct, there exists a marked diachronism between the Divisions C, D and E in the eastern and western London Basin. In the eastern London Basin the upper part of Div. C and the whole Div. D correspond then biostratigraphically with the lower part of Div. E in the western London Basin.

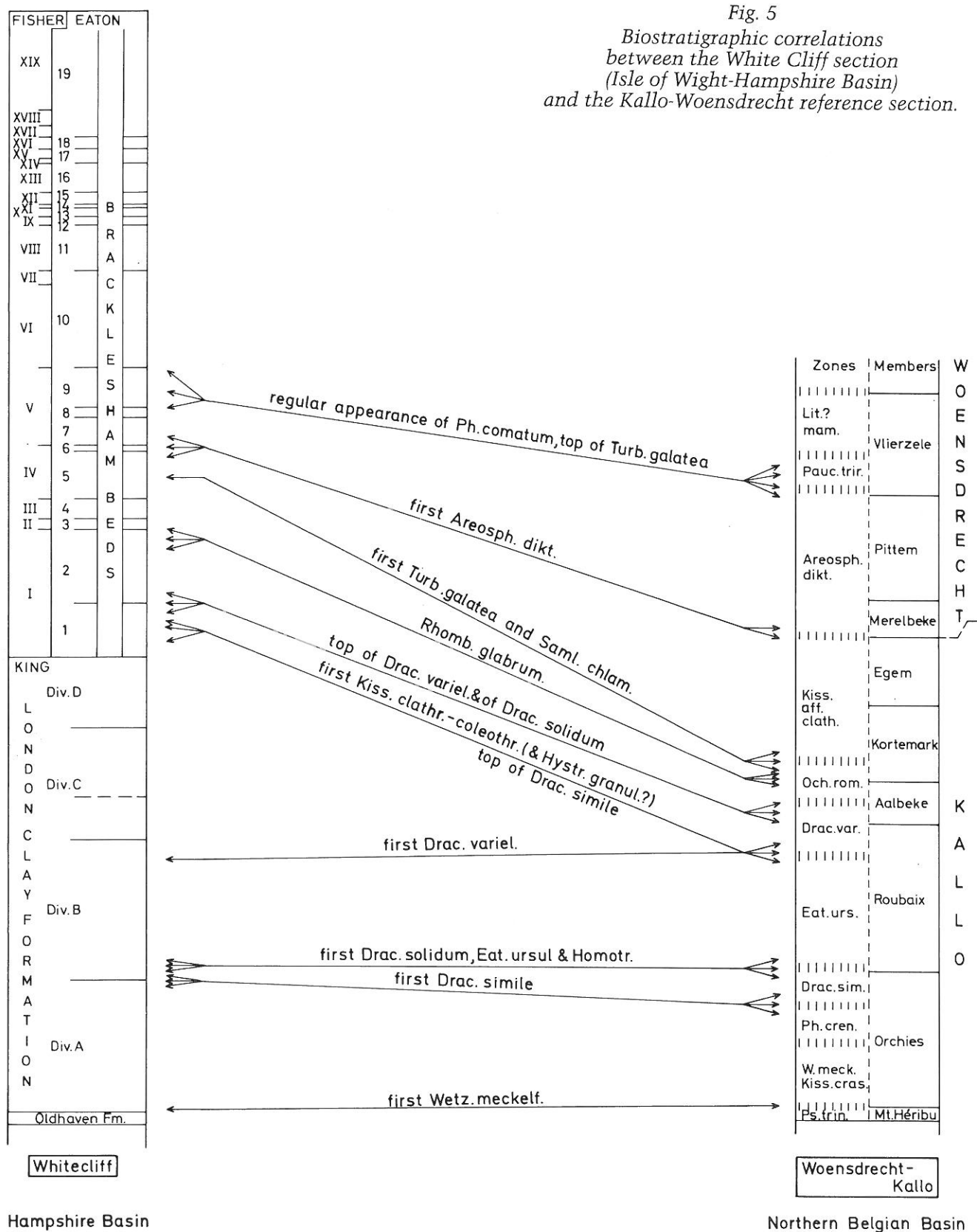
### • The *K. aff. clathrata* Zone

In the Kallo boring (northern Belgian Basin) the *K. aff. clathrata* Zone corresponds with the upper half of the Kortemark Silt and with the Egem Sand. At the base of this zone appear the first *T. galatea*. At Isle of Sheppey (eastern London Basin) *T. galatea* appears in the upper part of Div. E. At Kallo the top of the zone is marked by the regular appearance of *A. diktyoplokus* in the overlying deposits (Merelbeke Clay, Pittem Clay,...). At Isle of Sheppey *A. diktyoplokus* is recorded in one sample only, situated at the top of Div. D. The species is however absent in the following Div. E and in the palynomorph bearing samples in the basal part of the overlying Virginia Water Formation. For that reason I suppose that the uppermost part of Div. E and at least the lower levels of the Virginia Water Formation at Isle of Sheppey are the equivalent of some part of our *K. aff. clathrata* Zone at Kallo. In the western London Basin sections no species have been mentioned which allow to decide whether the equivalent of our *K. aff. clathrata* Zone was deposited or not.

### • The *A. diktyoplokus* Zone, *P. triradiata* Zone and *L. ? mamellatum* Zone

In the eastern London Basin sections at Isle of Sheppey and Herne Bay deposits corresponding with our *A. diktyoplokus* Zone up to the *L. ? mamellatum* Zone can not be indicated with certainty. In the western London Basin sections we can only try a correlation of the outcropping Middle Bagshot Beds at Shapley-Heath with the Woensdrecht section in the northern Belgian

Fig. 5  
 Biostratigraphic correlations  
 between the White Cliff section  
 (Isle of Wight-Hampshire Basin)  
 and the Kallo-Woensdrecht reference section.



Basin: *P. comatum* is recorded a first time at about 3,5 m above the base of the Middle Bagshot Beds while *A. robustum* disappears about 7 m higher. In the northern Belgian Basin the distribution of both species overlaps each other too in the lower part of our *L. ? mamellatum* Zone. From the distribution of both species we suppose that the base of the Middle Bagshot Beds in the western London Basin may be somewhat older than our *L. ? mamellatum* Zone; maybe it corresponds to the transition between our *A. diktyoplokus* Zone and *P. triradiata* Zone (?).

## B. The Hampshire Basin

In the Hampshire Basin the reference section of the Ypresian deposits is situated at White Cliff (Isle of Wight). The studies on organic-walled microfossils from this section have been published by DAVEY *et al.* (1966), EATON (1976), COSTA & DOWNIE (1976) and BUJAK *et al.* (1980). The most recent lithostratigraphy of these deposits was given by KING (1981) and EATON (1976). From the tables of distribution of dinoflagellates and from comments presented in these publications it has been possible to correlate the White Cliff section with our Woensdrecht-Kallo reference section in the northern Belgian Basin (fig. 5).

## COMMENTS

### • Basal Ypresian deposits

At White Cliff one notes at the base of Div. A<sub>2</sub> the presence of *W. meckelfeldensis*. This species appears in the Kallo section about three metres above the base of the Ypresian deposits. The equivalent of our *P. trinema* Zone was not deposited at White Cliff. The underlying Oldhaven Formation is somewhat older. Indeed, our *P. trinema* Zone is grosso modo the equivalent of the *W. astra* Zone and neither *P. trinema* or *W. astra* are recorded in the Oldhaven Formation.

### • The *E. ursulae* — *D. varielongitudum* Zone transition

COSTA & DOWNIE (1976, p. 594) mention the record of *D. varielongitudum* near the top of the London Clay. According to KING (1981, p. 116) this record is situated at 71 m above the base of the London Clay in the uppermost part of Div. B. The interval of the first record of *D. varielongitudum* up to the earliest appearance of *K. clathrata-coleothrypta* covers the uppermost part of Div. B, the whole Division C and D, and the lowermost part of the Bracklesham Bed I. At Kallo (northern Belgian Basin) *D. varielongitudum* and *K. clathrata-coleothrypta* appear together. This means that the sedimentation nearly stopped for a certain lapse of time at Kallo while at White Cliff it continued from the top of Div. B to the lower part of Bracklesham Bed I. That interval corresponds grosso modo with the glauconitic bed at Kallo — 305 m correlated with the one at Tielt — 101,5 m (Glauconiferous Bed of Tielt). A large part of this interval at White Cliff contains no palynomorphs. So the biostratigraphically valuable information is

scarce and the sudden difference in rate of sedimentation between White Cliff and Kallo may be overestimated. No doubt there was a difference because it is also noted at the same biostratigraphic level in our comparison of the Kallo sequence with the one at Isle of Sheppey (eastern London Basin).

### • The higher zones

The succession of several biostratigraphically significant species is the same in the Bracklesham Beds at White Cliff as in the higher Ypresian members of the Woensdrecht-Kallo section.

*R. glabrum* was recorded at Kallo in our *O. romanum* Zone and recorded in White Cliff in the uppermost part of Bracklesham Bed I.

The appearance of *T. galatea* and *S. chlamydophora* near the base of our *K. aff. clathrata* Zone is situated at White Cliff in the middle of Bracklesham Bed IV.

*A. diktyoplokus* is recorded for the first time in the northern Belgian Basin near the transition of the Egem Sand to the Merelbeke Clay; its earliest appearance at White Cliff is situated near the transition between Bracklesham Beds IV and V. In the northern Belgian Basin the top of the range of *T. galatea* is soon followed by the regular appearance of *P. comatum*. At White Cliff the ranges of both species overlap each other in the upper part of Bracklesham Bed V. This upper part of Bracklesham Bed V can best be correlated with our *P. triradiata* Zone. The transition of the Ypresian to the Lutetian is situated near the top of our *L. ? mamellatum* Zone and can be traced at White Cliff at the base of the Bracklesham Bed VI in which the Lutetian large foraminifer *Nummulites laevigatus* has been recorded.

The rate of sedimentation was somewhat higher in the Bracklesham Beds I up to the middle of IV at White Cliff than in the corresponding *D. varielongitudum* + *O. romanum* Zones in the Kallo sequence. On the contrary, the sedimentation was less pronounced from the middle of Bracklesham Bed IV up to the top of Bed V when compared with the corresponding *K. aff. clathrata* + *A. diktyoplokus* + *P. triradiata* + *L. ? mamellatum* Zones in the Woensdrecht-Kallo reference section.

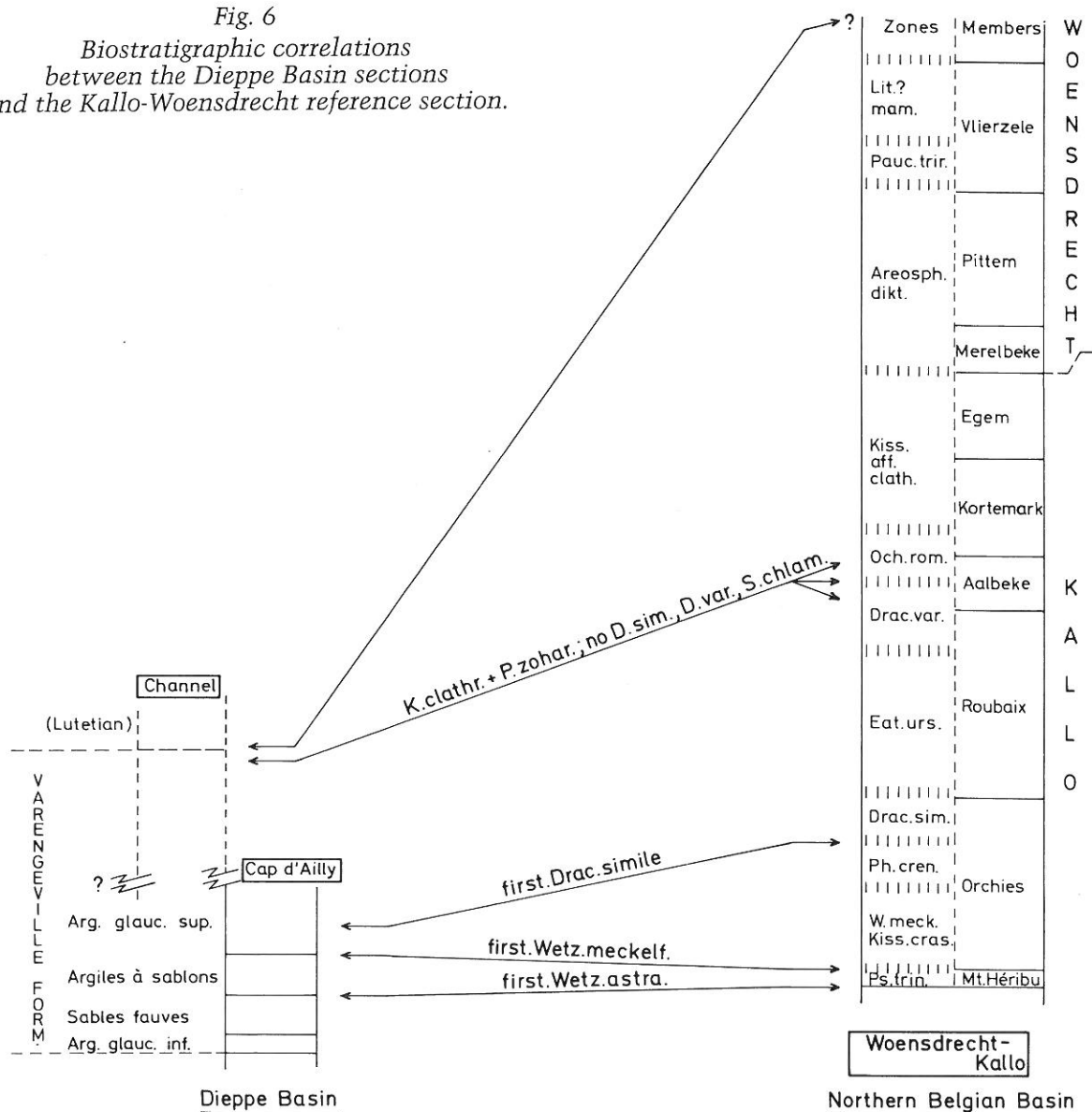
## C. Dieppe Basin (fig. 6)

In the Dieppe Basin the Ypresian deposits belong to the Varengeville Formation. The organic-walled microfossils in this formation were studied by GRUAS-CAVAGNETTO and the results published in GRUAS-CAVAGNETTO (1970), AUFFRET & GRUAS-CAVAGNETTO (1975), CHATEAUNEUF & GRUAS-CAVAGNETTO (1978) and GRUAS & BIGNOT (1985). The studied samples come from the cliff sections to the west-southwest of Dieppe (Cap d'Ailly and Sotteville-sur-Mer) and from offshore deposits in the Channel at about 40 to 50 Km in face of the mentioned cliff sections.

From the comments in GRUAS & BIGNOT (1985, pp. 119-120, text-fig. 2) it appears that the "Argiles glauconieuses inférieures" at Cap d'Ailly,



Fig. 6  
Biostratigraphic correlations  
between the Dieppe Basin sections  
and the Kallo-Woensdrecht reference section.



corresponding with the "Série de la Pointue" at Sotteville-sur-Mer, are older than the *W. astra* Zone. *W. astra* appears higher, in the base of the "Argiles à sablons" which are separated from the "Argiles glauconieuses inférieures" at Cap d'Ailly by the "Sables fauves" in which no organic-walled microfossils have been found. These "Argiles à sablons", at least their upper part, can be correlated with our *P. trinema* Zone. The age of the "Argiles glauconieuses inférieures" and perhaps of the "Sables fauves" too is thus older than the basal Ypresian deposits in the Belgian Basin.

The transition to the next *W. meckelfeldensis* Zone is recognised at Cap d'Ailly already near the transition of the "Argiles à sablons" to the "Argiles glauconieuses supérieures". Higher in the "Argiles glauconieuses supérieures" one enters the *D. simile* Zone. In the uppermost Ypresian deposits sampled offshore in the Channel

*K. clathrata* has been recorded together with *P. zoharyi* (= *P. subtile* in AUFRET & GRUAS-CAVAGNETTO, 1985, p. 650) and with *Homotryblum* species. In these samples one notes furthermore the absence of some significant species, namely *D. simile*, *D. varilongitutum* and *S. chlamydophora*. Such a species combination suggests us that the uppermost Ypresian deposits in the Dieppe Basin correspond with the upper part of our *D. varilongitutum* Zone and the lower part of our *O. romanum* Zone.

From these correlations with the Kallo reference section in the northern Belgian Basin appears that an important hiatus corresponding at least to our *K. aff. clathrata* + *A. diktyoplokus* + *P. triradiata* + *L. ? mamellatum* Zones separates the Ypresian deposits in the Dieppe Basin from the overlying Lutetian deposits.

## D. Paris Basin

The Ypresian deposits in the Paris Basin have been studied in several outcrops and borings mainly by GRUAS-CAVAGNETTO and by CHATEAUNEUF. The information which was published in CHATEAUNEUF & GRUAS-CAVAGNETTO (1968), GRUAS-CAVAGNETTO (1968), CHATEAUNEUF & GRUAS-CAVAGNETTO (1978) and LAURAIN *et al.* (1983) is not as explicit as the information about the dinoflagellate record in the corresponding deposits of the London and Hampshire Basins. From the available comments one can understand that the assemblages are in general rather poor, due to marginal marine or brackish environmental conditions during sedimentation and probably too as a result of later oxidation of the deposits.

It was unfortunately not possible to present here a figure illustrating correlations between a reference section in the Paris Basin with the Woensdrecht-Kallo reference section in the northern Belgian Basin.

The following, rather imprecise correlations are proposed between the Zones which we propose for the Belgian Basin and the Wetzeliellaceae Zones (cfr. COSTA, DENISON & DOWNIE, 1978) which CHATEAUNEUF & GRUAS-CAVAGNETTO (1978) have recognized in the Ypresian deposits of the Paris basin.

- *The P. trinema Zone*

In the Paris Basin the Ypresian sedimentation started at the time of deposition of the *P. trinema* Zone in the Belgian Basin. This zone corresponds grosso modo with the *W. astra* Zone which according to CHATEAUNEUF & GRUAS-CAVAGNETTO (1978, p. 62) is situated in the base of the "Sables de Laon" from the Cuisse-la-Motte boring.

- *The W. meckelfeldensis — K. crassoramosa + P. crenulatum Zones*

These zones in the Belgian Basin are the equivalent of the *W. meckelfeldensis* Zone sensu CHATEAUNEUF & GRUAS-CAVAGNETTO (*ibid.*, pp. 71-72) and are represented in the lower part of the "Sables de Laon" from the borings at Cuisse-la-Motte and at Le Tillet, also in the "Argiles à lignites du Soissonnais" in a boring at Mont Bernon, the type locality of the Sparnacian (LAURAIN *et al.*, 1983, pp. 244 and 250), and in the lignituous clays in a boring at Pont de Puteaux (western part of the Paris agglomeration) according to CHATEAUNEUF & GRUAS-CAVAGNETTO (1978, p. 62).

- *The D. simile + E. ursulae Zones*

These zones in the Belgian Basin correspond with the *D. simile* Zone sensu CHATEAUNEUF & GRUAS-CAVAGNETTO (*ibid.*, p. 73) situated in the higher part of the "Sables de Laon" in the Cuisse-la-Motte boring.

- *The gap between the E. ursulae Zone and the D. varielongitudum Zone*

In the Belgian Basin we have noted a gap between the *E. ursulae* Zone and the *D. varielongitudum* Zone. It corresponds with the *D. varielongitudum* Zone sensu CHATEAUNEUF & GRUAS-CAVAGNETTO (*ibid.*, p. 73) in which *D. varielongitudum* is not yet accompanied by *K. coleothrypta-clathrata*.

It corresponds in the Paris Basin with the uppermost part of the "Sables de Laon" in the Cuisse-la-Motte boring and with some part of the lignituous clays in a boring at La Défense (western part of the Paris agglomeration) (CHATEAUNEUF & GRUAS-CAVAGNETTO, *ibid.*, p. 62).

- *The D. varielongitudum Zone*

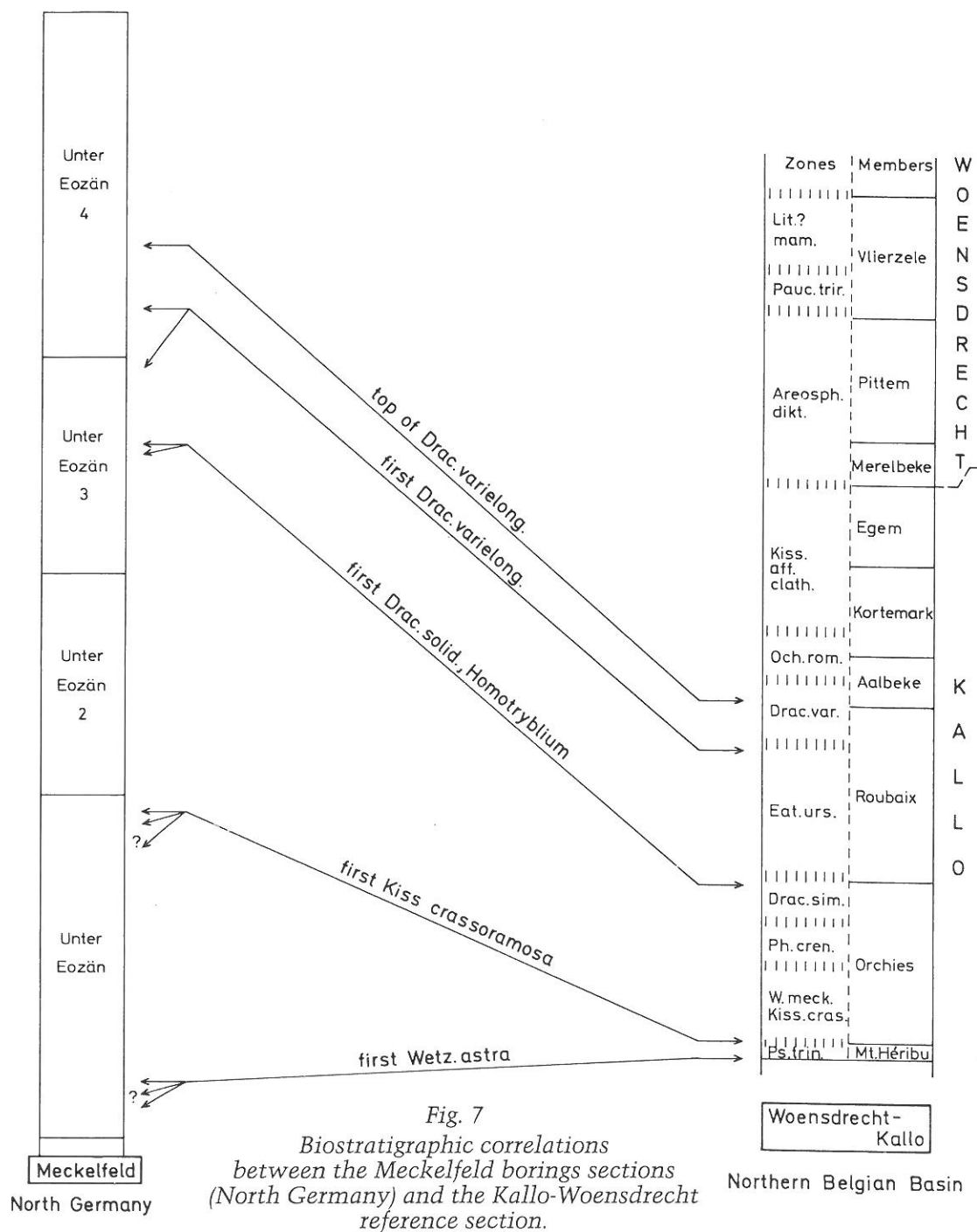
In the lower part of this zone in the Belgian Basin *D. varielongitudum* is recorded. The species is there accompanied by *K. clathrata-coleothrypta*. This lower part corresponds thus with the lowermost part of the *K. coleothrypta* Zone sensu CHATEAUNEUF & GRUAS-CAVAGNETTO (*ibid.*, p. 73) which is situated in the "Sables d'Aizy" and the "Sables de Pierrefond" (which form together the "Sables de Cuisse" in the quarry at Cuisse), and in the succeeding "Argiles de Laon" from a boring at Drancy (northeastern part of the Paris agglomeration). In these "Argiles de Laon" *D. varielongitudum* was recorded together with *K. coleothrypta*, *D. simile* and *D. solidum* (CHATEAUNEUF & GRUAS-CAVAGNETTO, *ibid.*, p. 64).

- *The O. romanum Zone up to the L. ? mamellatum Zone*

No *O. romanum* nor other species characterizing the *O. romanum* Zone and the following *K. aff. clathrata* Zone, *A. diktyoplokus* Zone, *P. triradiata* Zone or *L. ? mamellatum* Zone in the Belgian Basin have been recorded in the "Argiles de Laon" or any other Ypresian deposits which in the Paris Basin are directly followed by the Lutetian deposits. We must think thus that in the Paris Basin an important sedimentary gap is recorded, which corresponds probably with the *O. romanum* Zone up to the *L. ? mamellatum* Zone in the Belgian Basin.

## E. North Germany

H. GOCHT (1969) has described the organic-walled microfossils in Paleogene deposits from borings at Meckelfeld, to the south of Hamburg. The deposits "Unter Eozän 1" and the lower part of "Unter Eozän 2" were sampled in the boring Meckelfeld 86; the upper deposits of "Unter Eozän 3" and a section through "Unter Eozän 4" were sampled in the boring Meckelfeld 87. In the table of species distribution (GOCHT, *ibid.*, table 1) some species are noted which allow correlations with the Woensdrecht-Kallo reference section in the northern Belgian Basin (fig. 7).



• *P. trinema* Zone

This zone corresponds, as we have seen higher, grosso modo with the *W. astra* Zone. *W. astra* was probably recorded by GOCHT (*ibid.*, pp. 21-22, pl. 10, fig. 8, text-fig. 14) as *Wetzelilla* sp. 1 in the samples 10 and probably too in sample 5, both from the "Unter Eozän 1" deposits. No other real *Wetzelilla* spp. are observed in that part of the "Unter Eozän 1".

*Remark:* Sample 10 is situated above volcanic ash (tuffit) layers; sample 5 below them. If the *W. sp. 1* from sample 5 corresponds also with *W. astra*, the first occurrence of that species is older than

accepted until now, as the ash bearing deposits are considered to be situated just below the base of the *W. astra* Zone.

- *W. meckelfeldensis* — *K. crassoramosa* Zone + *P. crenulatum* Zone + *D. simile* Zone

*K. crassoramosa* was recorded by GOCHT (*ibid.*, pp. 16-17, pl. 9, fig. 4) as *W. clathrata*. Its earliest appearance is situated in the sample 11 near the top of "Unter Eozän 1" and accompanied by *W. lunaris*. The base of our *W. meckelfeldensis*-*K. crassoramosa* Zone corresponds thus with the upper part of the "Unter Eozän 1" deposits at Meckelfeld.

- *E. ursulae* Zone

Higher in the Meckelfeld deposits *Homotryblum* sp., recorded by GOCHT (*ibid.*, p. 59, pl. 2, fig. 10) as *Hystriosphæridium* cf. *siphoniphorum*, and *Dracodinium solidum* are recorded for the first time near the middle of "Unter Eozän 3".

*E. ursulae* was not recorded but in the Belgian Basin *Homotryblum* spp. and *D. solidum* appear together at the base of our *E. ursulae* Zone. Thus the base of our *E. ursulae* Zone corresponds with the levels midway the "Unter Eozän 3" deposits.

- *Sedimentary gap between our E. ursulae* Zone and *D. varielongitutum* Zone, + the *D. varielongitutum* Zone

The first *D. varielongitutum* was recorded by GOCHT (*ibid.*) in samples a little below the transition from "Unter Eozän 3" to "Unter Eozän 4". The species was not recorded in the samples 30 and 31 in the lower part of "Unter Eozän 4" but appears again more frequently in sample 32 and remains present in the assemblages of the following fifteen metres of deposits. From this distribution we can conclude that a part of the section in the Meckelfeld boring 87 covering the uppermost levels of "Unter Eozän 3" and the lower half of "Unter Eozän 4" corresponds probably with the sedimentary gap between our *E. ursulae* Zone and *D. varielongitutum* Zone and with our following *D. varielongitutum* zone.

- *O. romanum* Zone + *K. aff. clathrata* Zone + *A. diktyoplokus* Zone + *P. triradiata* Zone + *L. ? mamellatum* Zone

In the higher "Unter Eozän 4" deposits no significant species are recorded which characterize the *O. romanum* Zone or higher zones in the Belgian Basin. No further correlations can be made. We think that the rest of "Unter Eozän 4" may correspond with the higher part of our *D. varielongitutum* Zone and possibly to our *O. romanum* Zone.

It is improbable that deposits corresponding with our *K. aff. clathrata* Zone or higher zones are present in the Lower Eocene deposits at Meckelfeld because several significant species which should normally have been found in that case, have not been recorded there.

## F. Danish Basin

The organic-walled microfossils in the Ypresian deposits of Denmark have been studied by HANSEN (1979), HEILMANN-CLAUSEN (1982, 1983 and 1985), HEILMANN-CLAUSEN *et al.* (1985) and NIELSEN *et al.* (1986).

The Ypresian deposits are grouped in the Røsnaes Formation (Knudshoved Member + R<sub>1</sub> up to R<sub>6</sub>) and in the lower part of the overlying Lillebaelt Formation (L<sub>1</sub> and L<sub>2</sub>).

The lowermost part of the Røsnaes Formation, the Knudshoved Member, occurs only in the

western Limfjord area where it overlies the Upper Paleocene Fur Formation (alias Mo Clay or Moe Formation). The higher members of the Røsnaes Formation (R<sub>1</sub> up to R<sub>6</sub>) and the lower members (L<sub>1</sub> and L<sub>2</sub>) of the Lillebaelt Formation are well represented in clay pits at Ølst and Hinge (eastern part of Jutland) and in the Østerrende Store Baelt borehole n° 83101 (western coast of Zealand). In that area these Ypresian deposits rest on the Upper Paleocene Ølst Formation which is a lateral equivalent of the Fur Formation (see HEILMANN-CLAUSEN *et al.*, 1985, text-figs. 4 and 8).

From the comments on the assemblages of organic-walled microfossils in these deposits, a correlation scheme can be proposed between the Ypresian deposits in Denmark and the Woensdrecht-Kallo reference section in the northern Belgian Basin (fig. 8). In fig. 8 the vertical scale of the deposits at Knuden and in the Østerrende Store Baelt boring has been exaggerated ten times in comparison with the scale of the Woensdrecht-Kallo section.

- *P. trinema* Zone

In the lowermost, silicified bed of the Knudshoved Member *W. astra* is recorded while *W. meckelfeldensis* or *K. crassoramosa* remain absent. This lowermost bed of the Knudshoved Member corresponds thus with our *P. trinema* Zone (equivalent of the *W. astra* Zone).

- *W. meckelfeldensis* — *K. crassoramosa* Zone + *P. crenulatum* Zone

In the Knudshoved Member dark grey, silty clay is overlying the silicified lowermost bed. In this clay *W. meckelfeldensis* and *K. crassoramosa* appear for the first time. In the highest part of the Knudshoved Member (a green clay) and in the higher members R<sub>1</sub> up to R<sub>3</sub> no *D. simile* nor typical *E. ursulae* have been recorded.

It is thus probable that the remaining part of the Knudshoved Member, above its silicified lowermost bed, and the R<sub>1</sub> up to R<sub>3</sub> members correspond with our *W. meckelfeldensis* — *K. crassoramosa* Zone + *P. crenulatum* Zone.

- *D. simile* Zone + *E. ursulae* Zone

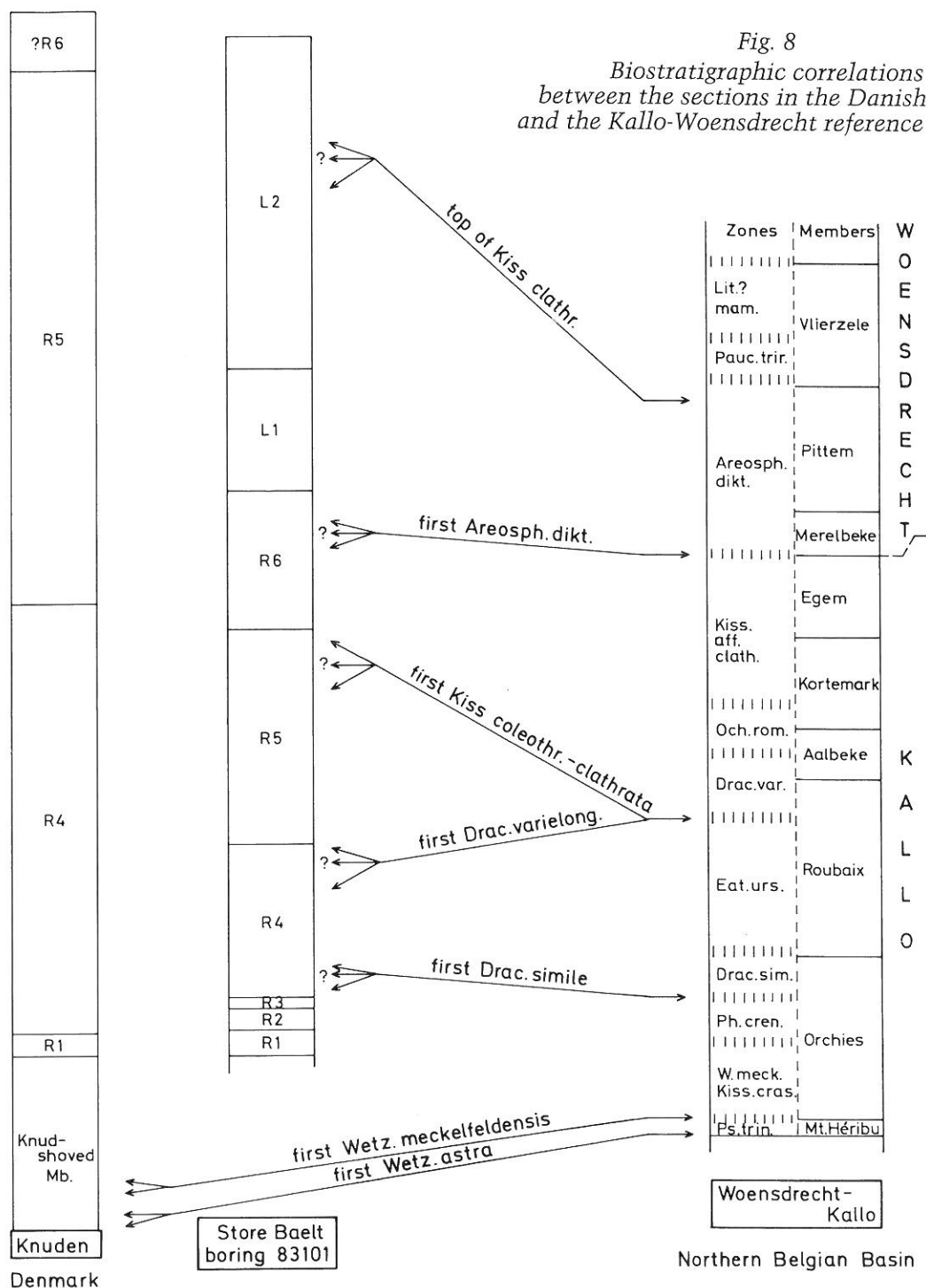
The first *D. simile* are recorded in the lower part of R<sub>4</sub> while in the upper part of that same R<sub>4</sub> Member *D. varielongitutum* is already found. This suggests that the lower part of R<sub>4</sub> corresponds grosso modo with our *D. simile* Zone + *E. ursulae* Zone.

- *Hiatus between our E. ursulae* Zone and our *D. varielongitutum* Zone

As we have noted higher when correlating the Ypresian deposits of the Belgian Basin with those of the London Basin and Hampshire Basin, the sedimentation was probably interrupted at Kallo on the transition between our *E. ursulae* Zone and *D. varielongitutum* Zone.

This hiatus corresponds with the interval between the first record of *D. varielongitutum* and the first record of *K. coleothrypta-clathrata*. It corresponds





with the higher part of R<sub>4</sub> and the lower part of R<sub>5</sub> [*K. coleothrypta-clathrata* is recorded a first time near the middle of R<sub>5</sub>].

- *D. varielongitutum* Zone

Near the middle of R<sub>5</sub> appears *K. coleothrypta-clathrata* while *O. romanum* is first recorded near the top of R<sub>5</sub>. The major part of the upper half of R<sub>5</sub> corresponds thus to our *D. varielongitutum* Zone.

- *O. romanum* Zone + *K. aff. clathrata* Zone

Near the top of R<sub>5</sub> and in the lower part of R<sub>6</sub> one encounters *O. romanum*. *K. aff. clathrata* was not recorded but *A. diktyoplokus* appears in the

higher part of R<sub>6</sub>. From this distribution we conclude that the top of R<sub>5</sub> and the lower half of R<sub>6</sub> correspond to our *O. romanum* Zone + *K. aff. clathrata* Zone.

- *A. diktyoplokus* Zone + *P. triradiata* Zone + *L. ? mamellatum* Zone

*A. diktyoplokus* appears in the upper part of R<sub>6</sub>. In the upper part of L<sub>2</sub> from the Østerrenden borehole n° 83101 occur three ash layers. Near the uppermost ash layer *Dracodinium pachydermum* (CARO, 1973) is recorded for the first time while *K. coleothrypta-clathrata* has disappeared. [NIELSEN *et al.*, 1986, fig. 6, p. 245].

At Ølst, somewhere between the second and the third ash layer in unit L<sub>2</sub>, *K. coleothrypta-clathrata* disappears (HEILMAN-CLAUSEN *et al.*, 1985, p. 307).

In the Woensdrecht section (northern Belgian Basin) *K. coleothrypta-clathrata* is absent from the *P. triradiata* + *L. ?mamellatum* Zones while *D. pachydermum* (CARO, 1973) (corresponding with *W. eoacena* in DE CONINCK, 1977, p. 44, pl. 3, fig. 10; pl. 4, figs. 1-4) appears at the top of the *L. ?mamellatum* Zone.

This suggests us that the upper part of R<sub>6</sub>, L<sub>1</sub> and a large part of L<sub>2</sub> can be correlated with our *A. diktyoplopus* + *P. triradiata* + *L. ?mamellatum* Zones and that the Ypresian-Lutetian transition is probably represented near the top of L<sub>2</sub>.

## CONCLUSION

Ypresian organic-walled phytoplankton totals about three hundred species, about three fourths of which are dinoflagellate cystforms. From their distribution in the basal Ypresian deposits of the Belgian Basin it seems that near the margin of the basin the environmental conditions at the time of sedimentation favoured production of fossilizable forms. Reworked species, mainly derived from Mesozoic deposits, are encountered especially in the lower members (Mont Héribu Member and Orchies Clay); their frequency is lower in the overlying Roubaix Clay and Kortemark Silt and becomes insignificantly low in the higher Ypresian deposits. The succession of organic-walled phytoplankton in the Ypresian deposits of the Belgian Basin is characterized by about fifty species

with a restricted stratigraphic range in that basin. Among these significant species, thirty-eight which are easily recognizable have been retained to define eleven zones (fig. 2). When comparing the assemblages from different outcrops and borings we are able to make biostratigraphic correlations (fig. 3), which attain a degree of precision comparable with that seen in the correlations done by STEURBAUT (in STEURBAUT & NOLF, 1986) on the base of calcareous nannofossils. Studying the investigations done in the surrounding basins, we note several similarities between the species distribution of dinoflagellate cysts in the Ypresian deposits from the Belgian Basin, London Basin, Hampshire Basin, Dieppe Basin, Paris Basin, North Germany and the Danish Basin. These similarities make biostratigraphic correlations possible between these areas (figs 4-8) and the Belgian Basin. A scheme (fig. 9) resumes these correlations with the indication of the biostratigraphical position of the principal members or divisions which were defined in the surrounding basins, relatively to our zonation.

This scheme gives also an idea of the representativity for the Ypresian of the deposits in each of the basins. We see that the most representative sections are found in the Hampshire Basin in the reference section of White Cliff at Isle of Wight, in the Belgian Basin in the combined reference section of Kallo-Woensdrecht, and in the Danish Basin in the combined section of Knuden (western Limfjord area) and in the Store Baelt boring 83101 (western Zealand coast). The combined section in Denmark is however about ten times thinner than the

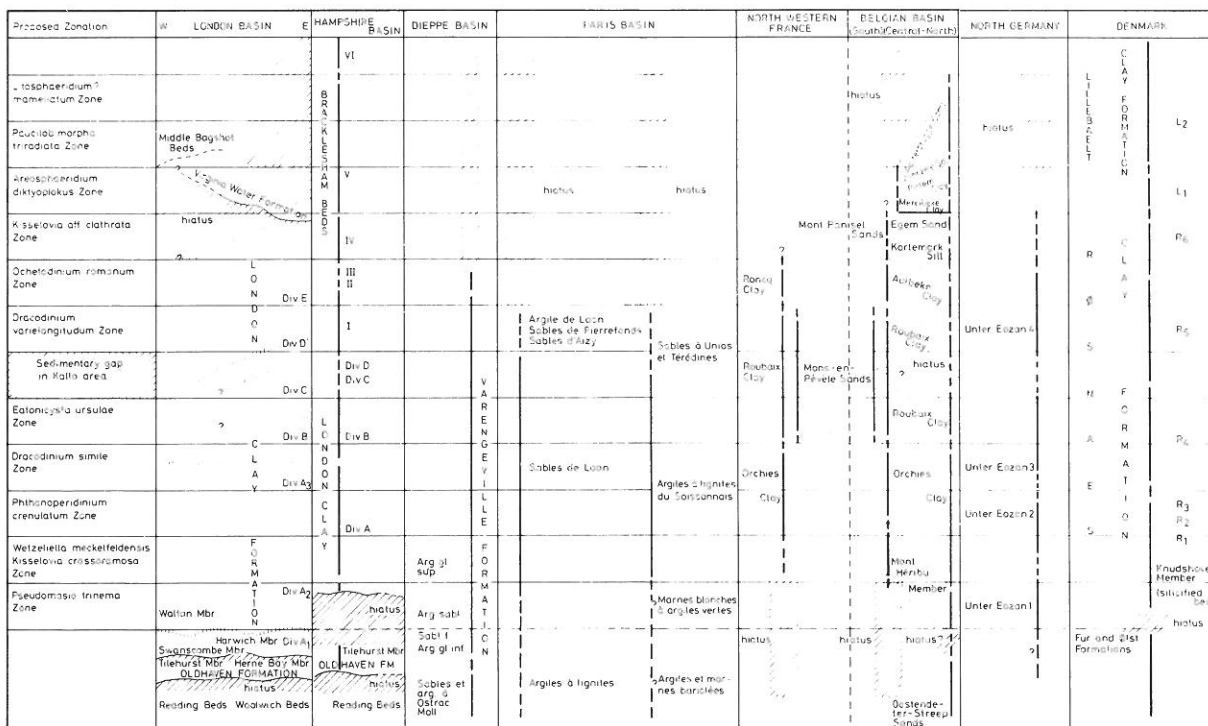


Fig. 9

Correlations of the N.W. European Ypresian lithostratigraphical units with the zones in the Kallo-Woensdrecht reference section.

| Proposed Zonation  | W | LONDON BASIN  | E | HAMPSHIRE BASIN | DIEPPE BASIN | PARIS BASIN  | NORTH WESTERN FRANCE | BELGIAN BASIN (South)(Central-North) | NORTH GERMANY | DENMARK                            |
|--|---|---|---|-----------------|--------------|--|----------------------|--------------------------------------|---------------|------------------------------------|
|  |   |   |   | VI              |              |  |                      |                                      |               | CLAY FORMATION                     |
| Litosphaeridium? mamellatum Zone                         |   |   |   |                 |              |  |                      | hiatus                               |               | CLAY FORMATION                     |
| Paucilabimorpha triradiata Zone                          |   | Middle Bagshot Beds   |   |                 |              |  |                      | hiatus                               | hiatus        | L2                                 |
| Areosphaeridium diktyoplakus Zone                        |   | Virginia Water Formation  |   | V               |              | hiatus   |                      | hiatus                               |               | L1                                 |
| Kisselovia aff. clathrata Zone                           |   | hiatus  |   | IV              |              |  | Mont Panisel Sands   | Egem Sand                            |               | R6                                 |
| Ochetodinium romanum Zone                                |   | L O N Div.E   |   | III             |              |  | Roncq Clay           | Kortemark Silt                       |               | CLAY                               |
| Dracodinium varielongitudum Zone                         |   | O N Div.D   |   | II              |              |  |                      | Aalbeke Clay                         |               | CLAY                               |
| Sedimentary gap in Kallø area                            |   | Div.C   |   | I               |              | Argile de Laon<br>Sables de Pierrefonds<br>Sables d'Aizy |                      | Roubaix Clay                         | Unter Eozän 4 | R5                                 |
| Eatonicysta ursulae Zone                                 |   | Div.B   |   |                 |              | Sables à Unios et Térédines                              | Roubaix Clay         | hiatus                               |               | S                                  |
| Dracodinium simile Zone                                  |   | Div.A3  |   |                 |              |  |                      | hiatus                               |               | N F                                |
| Phthanoperidinium crenulatum Zone                        |   | Div.A   |   |                 |              | Argiles à lignites du Soissonnais                        | Orchies Clay         | Orchies                              | Unter Eozän 3 | R4                                 |
| Wetzelia meckelfeldensis<br>Kisselovia crassoramosa Zone |   | Div.A2  |   |                 |              |  |                      | hiatus                               | Unter Eozän 2 | R3<br>R2<br>R1                     |
| Pseudomasia trinema Zone                                 |   | Walton Mbr.   |   |                 |              | Marnes blanches à argiles vertes                         |                      | hiatus                               | Unter Eozän 1 | Knudshoved Member (silicified bed) |
|  |   | Swanscombe Mbr.<br>Tilleshurst Mbr.<br>Hartley Bay Mbr.<br>OLDHAVEN FORMATION |   |                 |              | Argiles à lignites                                       |                      | hiatus                               |               | hiatus                             |
|  |   | Reading Beds Woodwich Beds  |   |                 |              | Sables et arg. à Ostrac. Moll.                           |                      | Oostende-ter-Striep Sands            |               | Fur and Ølst Formations            |





| L<br>U<br>T<br>E<br>T<br>I<br>A<br>N | NE Atlantic<br>-Rockall Plateau                        | Paris Basin<br>-Cuisse area               | Hampshire Basin<br>-White Cliff section                | Danish Basin<br>-western Limfjord<br>area<br>-Ølst-Hinge area | Belgian Basin<br>-Woensdrecht - Kallo<br>reference section     |
|--------------------------------------|--|---|--|---|--|
|                                      | COSTA, DENISON &<br>DOWNIE 1978<br>COSTA & MÜLLER 1978 | CHATEAUNEUF &<br>GRUAS-CAVAGNETTO<br>1978 | BUJAK, DOWNIE,<br>EATON & WILLIAMS<br>1980             | HEILMANN CLAUSEN<br>in press                                  | proposed zonation  |
| S<br>I<br>A<br>N                     | Kisselovia<br>coleothrypta<br>Zone                     | ?   | Kisselovia<br>fasciata<br>Zone                         | Dracodinium<br>pachydermis Zone                               |  |
|                                      |  |   | Areosphaeridium<br>arcuatum<br>Assemblage<br>Zone B-4  |   |  |
|                                      |  |   |  | Areosphaeridium<br>diktyoplokus Zone                          | Litosphaeridium ?<br>mamellatum Zone                           |
|                                      |  |   |  |   | Paucilobimorpha<br>triradiata Zone                             |
|                                      |  |   |  |   | Areosphaeridium<br>diktyoplokus Zone                           |
|                                      | Kisselovia<br>coleothrypta<br>rotundata Zone           |   | Pentadinium<br>lacticinctum<br>Assemblage Zone<br>B-2  | Kisselovia<br>coleothrypta<br>Zone                            | Kisselovia aff. clathrata<br>Zone                              |
|                                      |  |   | Homotryblum<br>abbreviatum<br>Assemblage<br>Zone B-1   |   | Ochetodinium romanum<br>Zone                                   |
|                                      | Kisselovia<br>coleothrypta<br>Zone                     |   |  |   | Dracodinium<br>varielongitutum<br>Zone                         |
|                                      | Dracodinium<br>varielongitutum<br>Zone                 | Dracodinium<br>varielongitutum<br>Zone    | Kisselovia<br>reticulata<br>Assemblage<br>Zone LC-3    | Dracodinium<br>varielongitutum<br>Zone                        | sedimentary gap in<br>the Kallo area                           |
|                                      | Dracodinium<br>simile<br>Zone                          | Dracodinium<br>simile<br>Zone             | Eatonicysta<br>ursulae<br>Assemblage Zone<br>LC-2      | Dracodinium<br>solidum Zone                                   | Eatonicysta ursulae<br>Zone                                    |
|                                      |  |   |  | Eatonicysta<br>ursulae Zone                                   | Dracodinium simile<br>Zone                                     |
| Y<br>P<br>R                          | Wetzeliella<br>meckelfeldensis<br>Zone                 | Wetzeliella<br>meckelfeldensis<br>Zone    | Deflandrea<br>phosphoritica<br>Assemblage Zone<br>LC-1 |   | Phthanoperidinium<br>crenulatum<br>Zone                        |
|                                      |  |   |  | Wetzeliella<br>meckelfeldensis<br>Zone                        | Wetzeliella meckelfeldensis<br>Kisselovia crassoramosa<br>Zone |
|                                      | Wetzeliella<br>astra<br>Zone                           | Wetzeliella<br>astra<br>Zone              |  | Wetzeliella<br>astra<br>Zone                                  | Pseudomasia trinema<br>Zone                                    |
| THANETIAN                            | ?  |   |  |   |  |

Fig. 10

Correlation of the zones in the Kallo-Woensdrecht reference section with the zones which were formerly proposed in the surrounding basins.

reference sections in the Hampshire Basin and Belgian Basin.

The basal Ypresian deposits in the northern Belgian Basin and in Denmark are a little older than in the Hampshire Basin. In the Kallo area (northern Belgian Basin) we note the existence, in all probability, of a gap in sedimentation between our local *E. ursulae* Zone and *D. varielongitudum* Zone. This gap corresponds grosso modo with the London Clay Divisions C and D at White Cliff (Hampshire Basin), and also with the upper part of R<sub>4</sub> + the lower part of R<sub>5</sub> in the Røsnaes Formation in Denmark. In the same scheme is also shown the change of position relatively to our zonation of the boundaries between certain London Clay divisions in the London Basin when going from west to east, and also of the boundaries between certain members in the Belgian Basin when going from northern to central and southern areas. As a result of these correlations we can correlate our zones with the different ones (based on dinoflagellates) which have been given for the Ypresian deposits in the different areas around the North Sea Basin (fig. 10).

As we see, the base of the *W. astra* Zone in the Rockall Plateau deposits (N.E. Atlantic) might be somewhat older than the base of our *P. trinema* Zone or of the *W. astra* Zone in the Paris, Hampshire and Danish basins. The sedimentary gap in the Kallo area between the local *E. ursulae* Zone and *D. varielongitudum* Zone corresponds with the *D. varielongitudum* Zone in the other basins. Our own *D. varielongitudum* Zone at Kallo corresponds with the lower part of the *K. coleothrypta* Zone as defined by COSTA, DENISON & DOWNIE (1978) and by HEILMAN-CLAUSEN (in press).

The Ypresian-Lutetian transition corresponds grosso modo with the upper limit of our *L. ?mamellatum* Zone and with the transition between the *A. diktyoplopus* Zone and the *D. pachydermum* Zone in the Danish Basin. In the other basins this transition is not reflected in the corresponding zonations.

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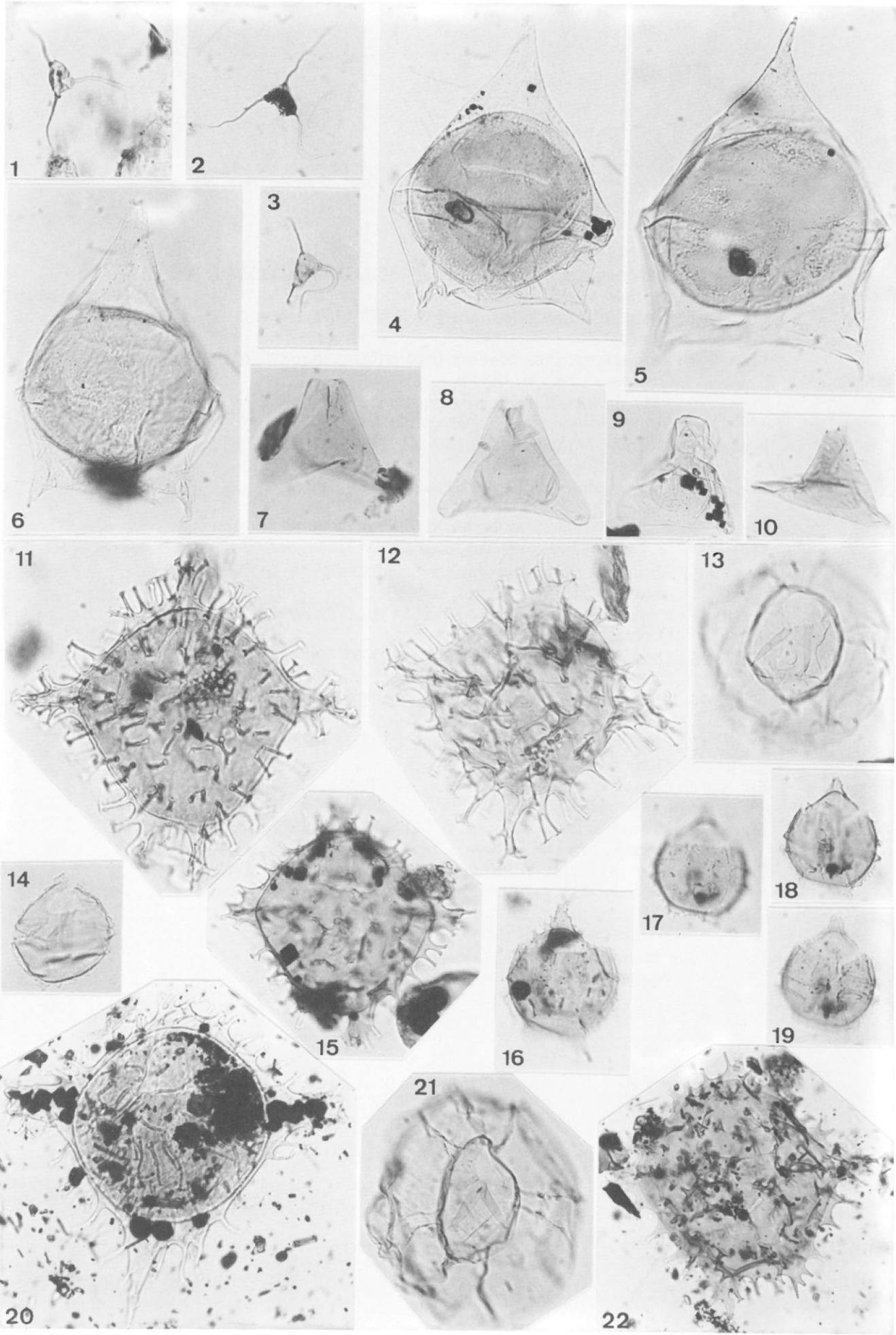
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## PLATE 1

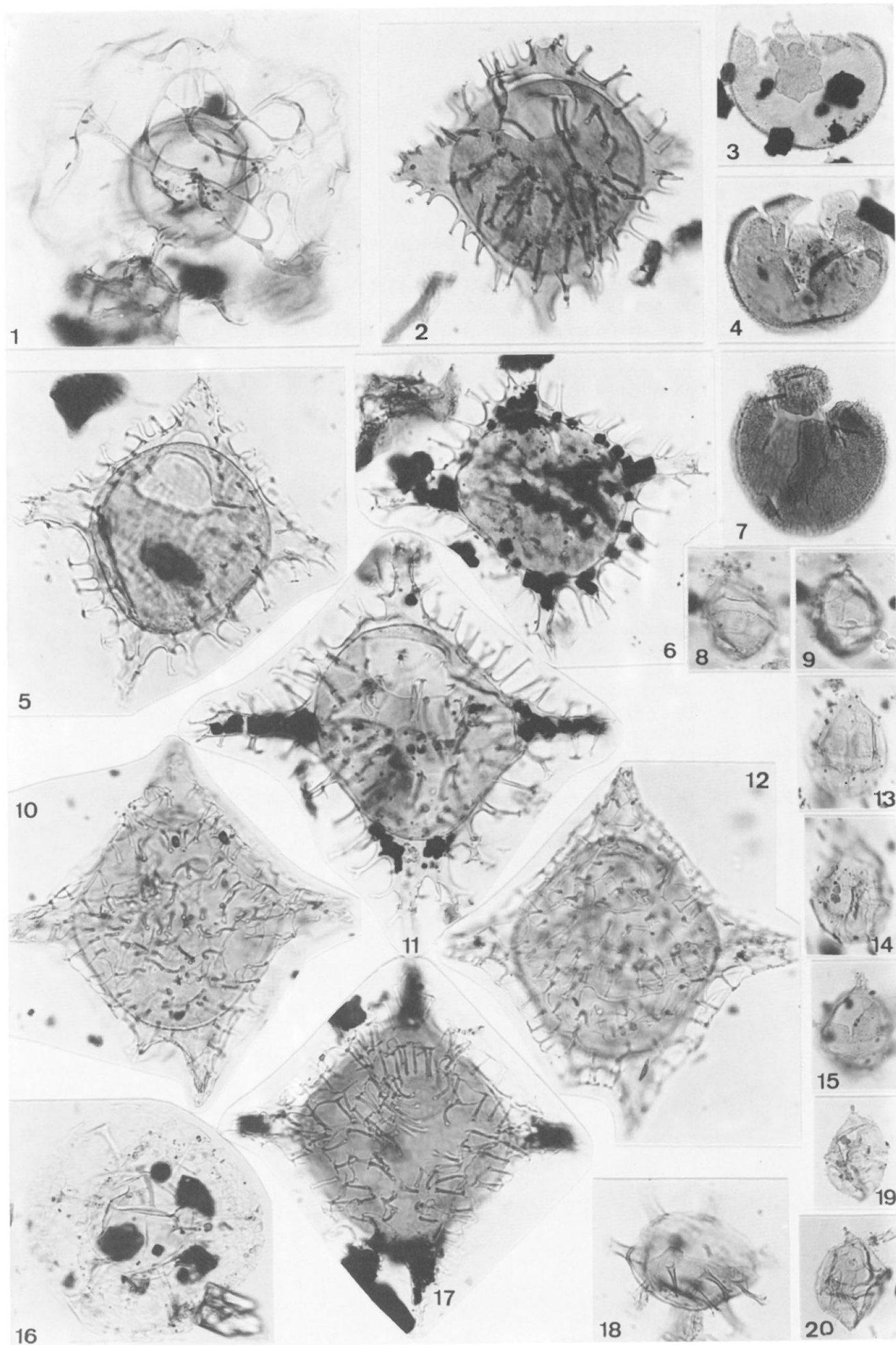
- Fig. 1 : *Pseudomasia trinema* DE CONINCK 1969. 500 ×.  
Quenast A1a, + 75 m, slide 6.
- Fig. 2 : *Pseudomasia trinema* DE CONINCK 1969. 500 ×.  
Quenast A1a, + 75 m, slide 5.
- Fig. 3 : *Pseudomasia trinema* DE CONINCK 1969. 500 ×.  
Quenast A2, + 75 m, slide 4.
- Fig. 4 : *Deflandrea oebisfeldensis* ALBERTI 1959. 500 ×.  
Overijse, + 27 m, slide 3.
- Fig. 5 : *Deflandrea oebisfeldensis* ALBERTI 1959. 500 ×.  
Quenast A4, + 77 m, slide 5.
- Fig. 6 : *Deflandrea oebisfeldensis* ALBERTI 1959. 500 ×.  
Quenast A1b, + 75 m, slide 4.
- Fig. 7 : *Trigonopyxidia ginella* (COOKSON & EISENACK 1960). 500 ×.  
Quenast B7, + 77 m, slide 1.
- Fig. 8 : *Trigonopyxidia ginella* (COOKSON & EISENACK 1960). 500 ×.  
Quenast B7, + 77 m, slide 3.
- Fig. 9 : *Trigonopyxidia ginella* (COOKSON & EISENACK 1960). 500 ×.  
Overijse, + 33.7 m, slide 4.
- Fig. 10 : *Trigonopyxidia ginella* (COOKSON & EISENACK 1960). 500 ×.  
Quenast B8, + 77 m, slide 1.
- Fig. 11 : *Wetziella astra* DENISON 1978. 500 ×.  
Quenast A4, + 77 m, slide 5.
- Fig. 12 : *Wetziella astra* DENISON 1978. 500 ×.  
St. Maur G240, + 69.5 m, slide 5.
- Fig. 13 : *Thalassiphora delicata* WILLIAMS & DOWNIE 1966. 500 ×.  
Quenast A6, + 79 m, slide 2.
- Fig. 14 : *Phthanoperidinium crenulatum* (DE CONINCK 1976). 500 ×.  
Overijse, + 38.5 m, slide 2.
- Fig. 15 : *Apectodinium hyperacanthum* (COOKSON & EISENACK 1965). 500 ×.  
Overijse, + 33.7 m, slide 5.
- Fig. 16 : *Phthanoperidinium crenulatum* (DE CONINCK 1976). 500 ×.  
Quenast B8, + 77 m, slide 3.
- Fig. 17-19 : *Phthanoperidinium crenulatum* (DE CONINCK 1976). 500 ×.  
Quenast A4, + 77 m, slide 4.
- Fig. 20 : *Dracodinium solidum* GOCHT 1955. 500 ×.  
Kallo, - 329.5 m, slide 2.
- Fig. 21 : *Thalassiphora delicata* WILLIAMS & DOWNIE 1986. 500 ×.  
Quenast A6, + 79 m, slide 2.
- Fig. 22 : *Apectodinium hyperacanthum* (COOKSON & EISENACK 1965). 500 ×.  
Tielt, - 101.5 m, slide 3.





## PLATE 2

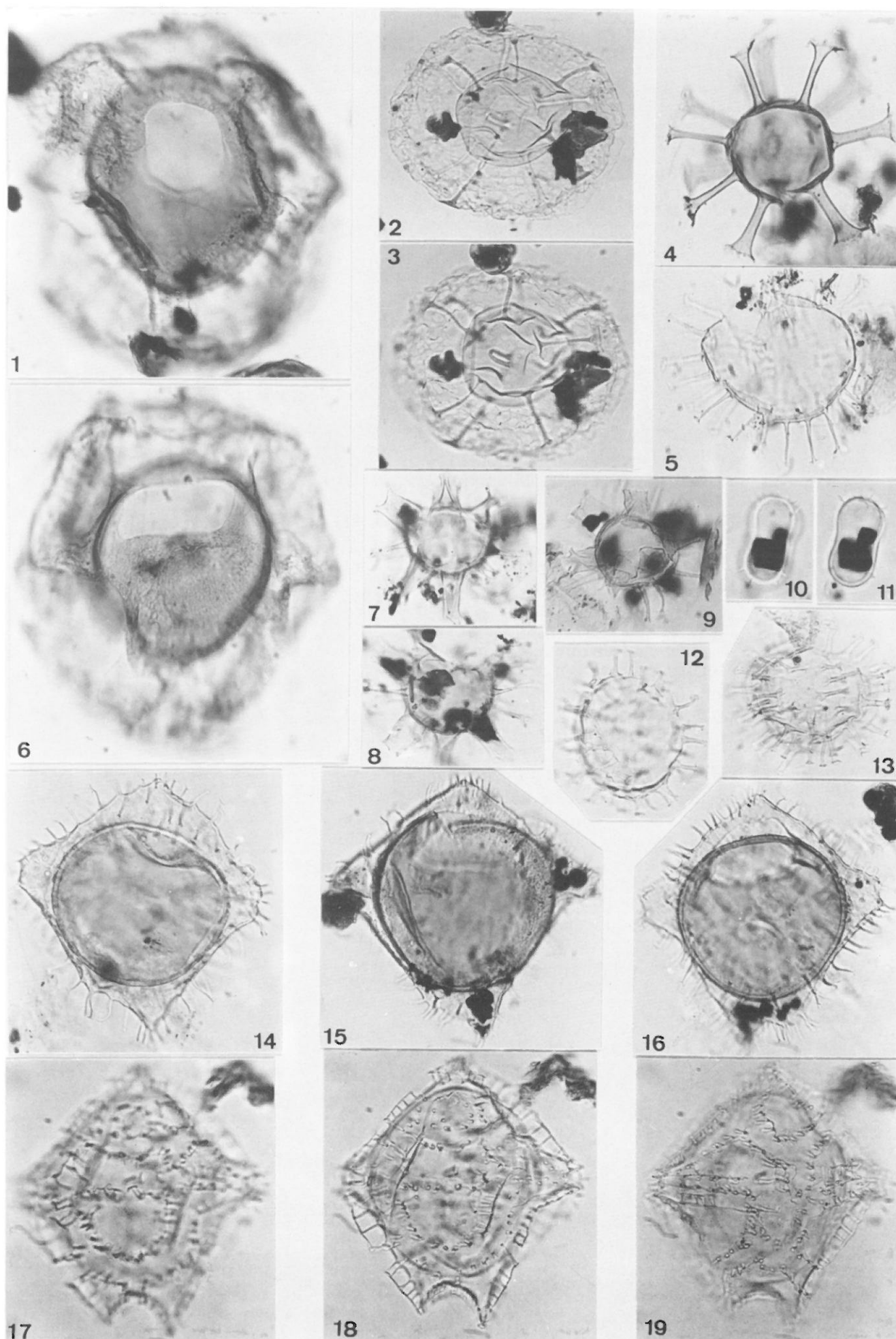
- Fig. 1 : *Adnatosphaeridium robustum* (MORGENROTH 1966). 500 ×.  
St. Maur G240, + 69.5m, slide 1.
- Fig. 2 : *Wetzeliiella meckelfeldensis* GOCHT 1969. 500 ×.  
Quenast B8, + 77m, slide 1.
- Fig. 3 : *Kallosphaeridium brevibarbatum* DE CONINCK 1969. 500 ×.  
Overijse, + 38.5m, slide 3.
- Fig. 4 : *Kallosphaeridium brevibarbatum* DE CONINCK 1969. 500 ×.  
Mons-Ghlin G245, + 49.3m, slide 4.
- Fig. 5 : *Wetzeliiella meckelfeldensis* GOCHT 1969. 500 ×.  
Quenast B8, + 77m, slide 1.
- Fig. 6 : *Dracodinium simile* (EISENACK 1954). 500 ×.  
Overijse, + 38.5m, slide 5.
- Fig. 7 : *Kallosphaeridium brevibarbatum* DE CONINCK 1969. 500 ×.  
St. Maur G240, + 69.5m, slide 1.
- Fig. 8-9 : *Phthanoperidinium echinatum* EATON 1976. 500 ×.  
Merelbeke sluice, + 0.5m, slide 9.
- Fig. 10, 12 : *Kisselovia crassoramosa* (WILLIAMS & DOWNIE 1866) 500 ×  
Orchies, + 27.5m, slide 3.
- Fig. 11 : *Dracodinium simile* (EISENACK 1954). 500 ×.  
Mons-Ghlin G245, + 49.3m, slide 2.
- Fig. 13-14 : *Phthanoperidinium echinatum* EATON 1976. 500 ×.  
Merelbeke sluice, - 3.5m, slide 4.
- Fig. 15 : *Phthanoperidinium echinatum* EATON 1976. 500 ×.  
Melle F-DB11, - 7m, slide 2.
- Fig. 16 : *Eatonicysta ursulae* (MORGENROTH 1966). 500 ×.  
Melle F-DB11, + 5.5m, slide 3.
- Fig. 17 : *Kisselovia crassoramosa* (WILLIAMS & DOWNIE 1966). 500 ×.  
Overijse, + 27m, slide 3.
- Fig. 18 : *Homotryblum pallidum* ? DAVEY & WILLIAMS 1966. 500 ×.  
Melle F-DB11, - 5m, slide 1 (filtered).
- Fig. 19 : *Phthanoperidinium echinatum* EATON 1976. 500 ×.  
Woensdrecht, - 459m, slide 1.
- Fig. 20 : *Phthanoperidinium echinatum* EATON 1976. 500 ×.  
Woensdrecht, - 459m, slide 3.



## PLATE 3

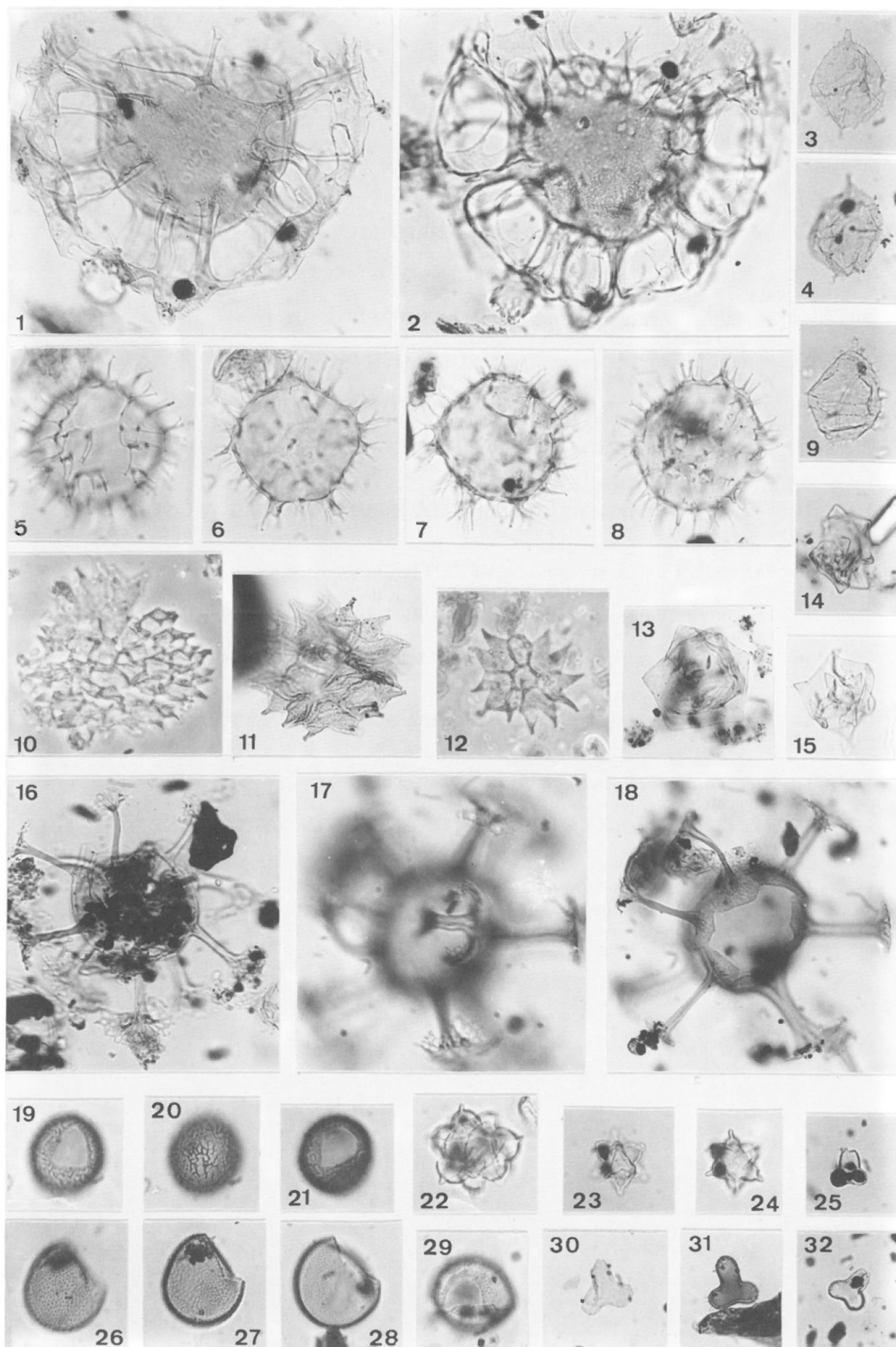
- Fig. 1 : *Thalassiphora pelagica* (EISENACK 1954). 500 ×.  
Mont Héribu G246, + 53.3 m, slide 2.
- Fig. 2-3 : *Eatonicysta ursulae* (MORGENROTH 1966). 500 ×.  
Melle F-DB11, + 5.5 m, slide 2.
- Fig. 4 : *Homotryblium pallidum*? DAVEY & WILLIAMS 1966. 500 ×.  
Melle F-DB11, - 5 m, slide 1 (filtered).
- Fig. 5 : *Polysphaeridium zoharyi* (ROSSIGNOL 1962). 500 ×.  
Heusden F-DB11, + 0.5 m, slide 1.
- Fig. 6 : *Thalassiphora pelagica* (EISENACK 1954). 500 ×.  
Quenast B8, + 77 m, slide 1.
- Fig. 7 : *Hystrichokolpoma granulatum* EATON 1976. 500 ×.  
Woensdrecht, - 441 m, slide 6.
- Fig. 8 : *Hystrichokolpoma granulatum* EATON 1976. 500 ×.  
Woensdrecht, - 429 m, slide 4.
- Fig. 9 : *Hystrichokolpoma granulatum* EATON 1976. 500 ×.  
Egem-Ampe, + 38.2 m, slide 5.
- Fig. 10-11 : *Diacrocanthidium spinigerum* DE CONINCK 1969. 1000 ×.  
Kallo, - 283.5 m, slide 1.
- Fig. 12 : *Polysphaeridium zoharyi* (ROSSIGNOL 1962). 500 ×.  
Aalbeke G80, + 43.5 m, slide 2.
- Fig. 13 : *Polysphaeridium zoharyi* (ROSSIGNOL 1962). 500 ×.  
Aalbeke G80, + 43.5 m, slide 1.
- Fig. 14 : *Dracodinium varielongitudum* (WILLIAMS & DOWNIE 1966). 500 ×.  
Kallo, - 288 m, slide 1.
- Fig. 15 : *Dracodinium varielongitudum* (WILLIAMS & DOWNIE 1966). 500 ×.  
Lauwe-Knok, + 26 m, slide 1.
- Fig. 16 : *Dracodinium varielongitudum* (WILLIAMS & DOWNIE 1966). 500 ×.  
Kallo, - 288 m, slide 1.
- Fig. 17-19 : *Kisselovia clathrata* (EISENACK 1938). 500 ×.  
Egem-Ampe, + 38.2 m, slide 2.





## PLATE 5

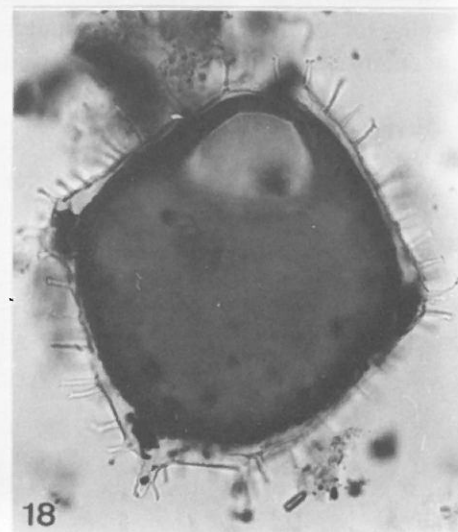
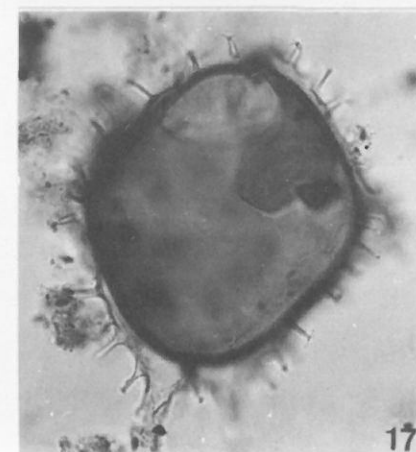
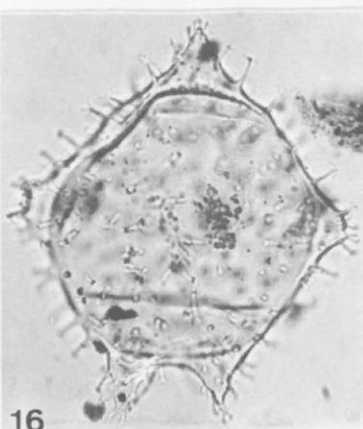
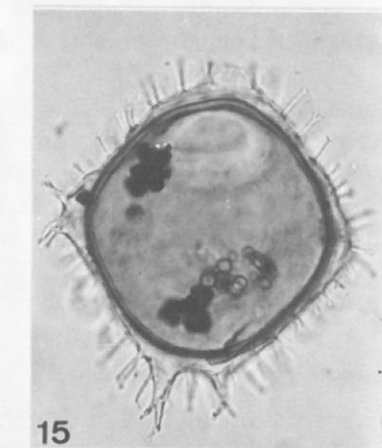
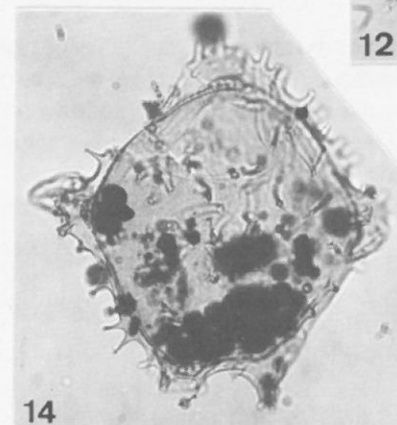
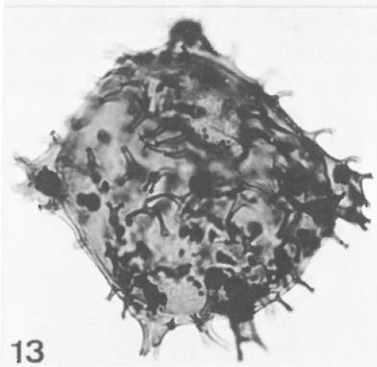
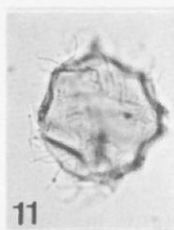
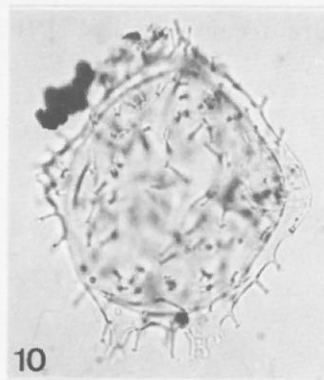
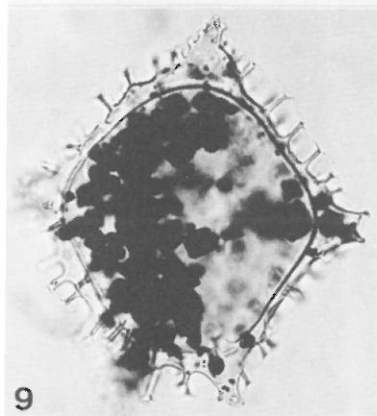
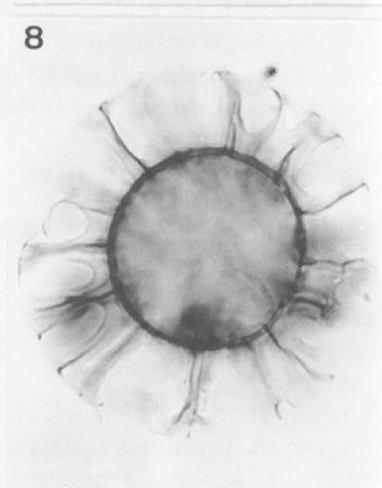
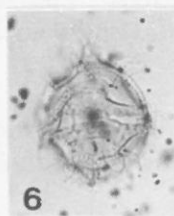
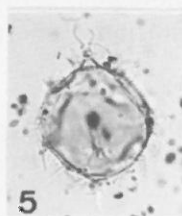
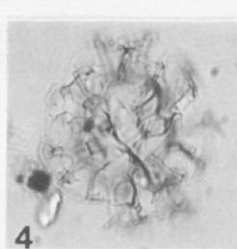
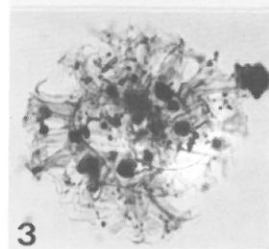
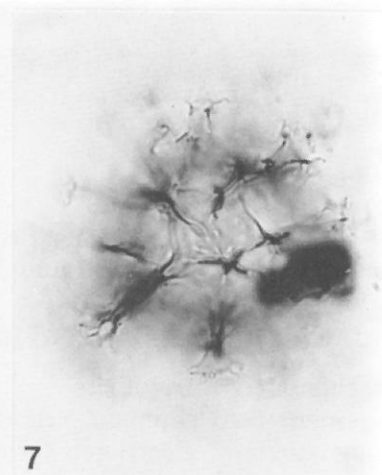
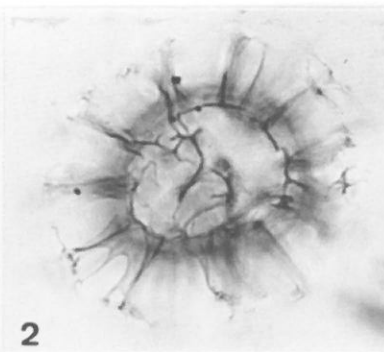
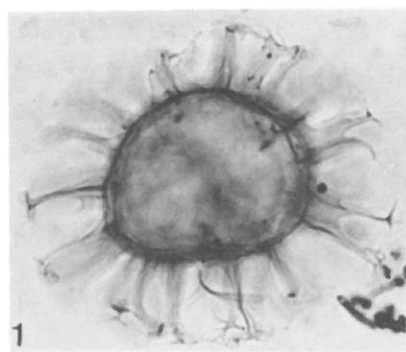
- Fig. 1-2 : *Glaphyrocysta exuberans* (DEFLANDRE & COOKSON 1955). 500 ×.  
Egem-ringbeek, + 28 m, slide 2.
- Fig. 3 : *Spinidinium* aff. *esso*i COOKSON & EISENACK 1967. 500 ×.  
Torhout-Pottebezemhoek, + 26 m, slide 4.
- Fig. 4 : *Spinidinium* aff. *esso*i COOKSON & EISENACK 1967. 500 ×.  
Torhout-Pottebezemhoek, + 26 m, slide 2.
- Fig. 5-6 : *Apectodinium homomorphum* (DEFLANDRE & COOKSON 1955). 500 ×.  
Egem-Ampe, + 38.2 m, slide 1.
- Fig. 7 : *Apectodinium homomorphum* (DEFLANDRE & COOKSON 1955). 500 ×.  
Egem-Ampe, + 38.2 m, slide 1.
- Fig. 8 : *Apectodinium homomorphum* (DEFLANDRE & COOKSON 1955). 500 ×.  
Egem-Ampe, + 38.2 m, slide 1.
- Fig. 9 : *Spinidinium* aff. *esso*i COOKSON & EISENACK 1967. 500 ×.  
Melle F-DB11, - 7 m, slide 1 (filtered).
- Fig. 10 : *Pediastrum* sp. 500 ×.  
Kallo, - 238 m, slide 2.
- Fig. 11 : *Pediastrum* sp. 500 ×.  
Woensdrecht, - 410 m, slide 3 (filtered).
- Fig. 12 : *Pediastrum* sp. 500 ×.  
Kallo, - 239 m, slide 3.
- Fig. 13 : *Pulvinosphaeridium* sp. 500 ×.  
Kallo, - 238 m, slide 3.
- Fig. 14 : *Pulvinosphaeridium* sp. 500 ×.  
Kallo, - 238 m, slide 2.
- Fig. 15 : *Pulvinosphaeridium* sp. 500 ×.  
Torhout-Pottebezemhoek, + 26 m, slide 3.
- Fig. 16 : *Areosphaeridium diktyoplo*kus (KLUMPP 1953). 500 ×.  
Melle F-DB11, - 4 m, slide 8 (filtered).
- Fig. 17-18 : *Areosphaeridium diktyoplo*kus (KLUMPP 1953). 500 ×.  
Melle F-DB11, - 5 m, slide 4.
- Figs. 19-20 : *Cerebrocysta bartonensis* BUJAK 1980. 500 ×.  
Heusden F-DB4, 0 m, slide 2 (filtered).
- Fig. 21 : *Cerebrocysta bartonensis* BUJAK 1980. 500 ×.  
Heusden F-DB4, 0 m, slide 3 (filtered).
- Fig. 22 : *Litosphaeridium* ? *mamellatum* DE CONINCK 1977. 500 ×.  
Woensdrecht, - 410 m, slide 2 (filtered).
- Figs. 23-24 : *Litosphaeridium* ? *mamellatum* DE CONINCK 1977. 500 ×.  
Kallo, - 208.9 m, slide 1 (filtered).
- Fig. 25 : *Paucilobimorpha triradiata* DE CONINCK 1986. 500 ×.  
Kallo, - 208.9 m, slide 1.
- Figs. 26-27 : *Pyxidopsis densepunctata* DE CONINCK 1985. 500 ×.  
Woensdrecht, - 459 m, slide 2.
- Fig. 28 : *Pyxidopsis densepunctata* DE CONINCK 1985. 500 ×.  
Woensdrecht, - 401 m, slide 2.
- Fig. 29 : *Pyxidopsis densepunctata* DE CONINCK 1985. 500 ×.  
Woensdrecht, - 429 m, slide 1.
- Fig. 30 : *Paucilobimorpha triradiata* DE CONINCK 1986. 500 ×.  
Melle F-DB11, - 4 m, slide 10 (filtered).



## PLATE 6

- Fig. 1-2 : *Impletosphaeridium rugosum* MORGENROTH 1966. 1000  $\times$ .  
Woensdrecht, - 410m, slide 1 (filtered).
- Fig. 3 : *Impletosphaeridium rugosum* MORGENROTH 1966. 500  $\times$ .  
Melle F-DB11, + 5m, slide 1 (filtered).
- Fig. 4 : *Impletosphaeridium rugosum* MORGENROTH 1966. 500  $\times$ .  
Melle F-DB11, - 5m, slide 1 (filtered).
- Figs. 5-6 : *Phthanoperidinium comatum* (MORGENROTH 1966). 500  $\times$ .  
Woensdrecht, - 410m, slide 4.
- Figs. 7-8 : *Impletosphaeridium rugosum* MORGENROTH 1966. 1000  $\times$ .  
Woensdrecht, - 441m, slide 2 (filtered).
- Fig. 9 : *Wetzeliiella* aff. *articulata* (sensu CHATEAUNEUF & GRUAS-CAVAGNETTO 1978).  
500  $\times$ .  
Woensdrecht, - 410m, slide 1 (filtered).
- Fig. 10 : *Wetzeliiella* aff. *articulata* (sensu CHATEAUNEUF & GRUAS-CAVAGNETTO 1978).  
500  $\times$ .  
Woensdrecht, - 385m, slide 1.
- Fig. 11 : *Phthanoperidinium comatum* (MORGENROTH 1966). 500  $\times$ .  
Woensdrecht, - 410m, slide 2 (filtered).
- Fig. 12 : *Phthanoperidinium comatum* (MORGENROTH 1966). 500  $\times$ .  
Egem-Ampe, + 40.3m, slide 2.
- Fig. 13 : *Wetzeliiella* aff. *articulata* (sensu CHATEAUNEUF & GRUAS-CAVAGNETTO 1978).  
500  $\times$ .  
Woensdrecht, - 410m, slide 2 (filtered).
- Fig. 14 : *Wetzeliiella* aff. *articulata* (sensu CHATEAUNEUF & GRUAS-CAVAGNETTO 1978).  
500  $\times$ .  
Woensdrecht, - 416.5m, slide 1.
- Fig. 15 : *Dracodinium pachydermum* (CARO 1973). 500  $\times$ .  
Woensdrecht, - 385m, slide 5.
- Fig. 16 : *Wetzeliiella* aff. *articulata* (sensu CHATEAUNEUF & GRUAS-CAVAGNETTO 1978).  
500  $\times$ .  
Woensdrecht, - 385m, slide 1.
- Fig. 17 : *Dracodinium pachydermum* (CARO 1973). 500  $\times$ .  
Woensdrecht, - 380m, slide 7.
- Fig. 18 : *Dracodinium pachydermum* (CARO 1973). 500  $\times$ .  
Woensdrecht, - 380m, slide 7.





# FACULTE POLYTECHNIQUE DE MONS



Créée en 1837 sous le nom d'Ecole des Mines de Mons, institution universitaire indépendante reconnue personne civile par la loi du 7 juillet 1920, la Faculté a fêté en 1987 ses 150 ans.

## Formation universitaire d'ingénieurs civils (5 ans)

- . Ingénieur civil architecte
- . Ingénieur civil chimiste (orientations : biotechnologies; céramiques; énergie; procédés)
- . Ingénieur civil électricien (orientations : automatique; énergie; informatique; télécommunications)
- . Ingénieur civil en informatique et gestion
- . Ingénieur civil mécanicien
- . Ingénieur civil métallurgiste (orientations : matériaux nouveaux; procédés)
- . Ingénieur civil des mines (orientations : grands travaux, environnement et risques; ressources)

## Diplômes complémentaires

- . Ingénieur civil en informatique et gestion (horaire décalé avec le CUNIC)
- . Ingénieur civil et Maîtrise en  
Automatique  
Energie  
Génie nucléaire  
Géologie  
Sécurité, Hygiène et Embellissement des lieux de travail
- . Maîtrise en Management de l'Innovation
- . Docteur en Sciences Appliquées - Maître en Sciences Appliquées
- . Docteur en Géologie Appliquée
- . Agrégé de l'enseignement supérieur

## Formation continue

- . Cycles longs : Certificats en - Analyse thermodynamique de l'énergétique industrielle; - Energétique des procédés industriels, récupération thermique; - Production et transport de l'énergie électrique; - Economies d'énergie dans le bâtiment; - Economies d'énergie dans l'industrie : étude de secteurs; - Réservoir engineering; Sciences nucléaires; - Techniques de sécurité; - Automatique; - Energie électrique; - Informatique; - Télécommunications
- . Cycles courts : Cours de recyclage et de spécialisation proposés en fonction de la demande industrielle

## Services aux étudiants

- . Cité estudiantine de 288 chambres individuelles, restaurant
- . Tutelle médicale - Service social - Mutuelle d'Editions
- . Cercles facultaires culturels et sportifs
- . Placement : Association des Ingénieurs de Mons (2 000 membres)

## Collaborations industrielles

- . Centre d'Etudes et de Recherches des Hautes Technologies (CERHT)
- . Participation des différents services avec les secteurs privé et public. Stages d'étudiants dans les entreprises
- . Laboratoires d'analyse et de mesure - Certifications
- . Ateliers équipés pour les réalisations complexes et les plus délicates
- . Centre de calcul et de traitement de l'information

*Renseignements :*

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